San Bernardino County
PIN# 9172 – Low Impact Development Guidance and Training for Southern California

Literature Review
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Final Draft

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List of Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
BAHM	Bay Area Hydrology Model
BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practice
Caltrans	California Department of Transportation
CASQA	California Stormwater Quality Association
CSO	Combined Sewer Overflow
CDS	Continuous Deflection Separator
HMP	Hydromodification Plan
HSPF	Hydrological Simulation Program-Fortran
IMP	Integrated Management Practice
LEED	Leadership in Energy & Environmental Design
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollution Discharge Elimination System
RVTS	Roadside Vegetated Treatment Sites
RWQCB	Regional Water Quality Control Board
TMDL	Total Maximum Daily Load
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SWRCB	State Water Resources Control Board
SUSMP	Standard Urban Stormwater Mitigation Plan
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	Statewide Water Resources Control Board
TAC	San Bernardino Technical Advisory Committee
USEPA	United States Environmental Protection Agency
WERF	Water Environment Research Foundation
WQV	Water Quality Volume
WWHM3	Western Washington Hydrology Model

Executive Summary

This literature review was conducted as a task for the Low Impact Development (LID) Guidance and Training for Southern California Project (LID Project). This effort is being funded by a Proposition 40 Grant and matching funds from local and regional governmental organizations. The purpose of this literature review is to provide communities with readily available information that can be used to integrate LID into their resource protection and regulatory programs. Criteria for the focus of the literature review were developed by the LID Project's Technical Advisory Committee (TAC). Based on the findings of the literature review, information gaps and research needs were identified and discussed for each of the criterion areas.

LID is an emerging science, and the first studies on the potential use of LID for water resource protection were conducted less than fifteen (15) years ago in Prince George's County, Maryland. The first published research and guidance documents on LID are less than ten (10) years old. The science of LID has also evolved from the use of Integrated Management Practices (IMPs), or small source control Best Management Practices (BMPs) to site design and comprehensive watershed and environmental planning strategies. Most of the research and implementation in the United States has occurred in coastal and estuarine environments along the East Coast and in the Northwest. There is a limited amount of research, implementation projects, and guidance documents that focus on the arid and semi-arid Southwest. The recent acceptance and integration of LID into municipal separate storm sewer (MS4) permits in California has generated a number of new LID pilot projects and regulations. This has generated a subsequent demand for information on cost, effectiveness, benefits, maintenance, institutional issues, and other guidance information that is required for integration of LID into local and regional programs.

LID has changed the stormwater management "landscape" because it is an approach which applies integrated natural system function into stormwater strategies that have typically been focused on end of pipe storage/treatment systems. Many of the LID solutions have promise in meeting multiple planning, community development, environmental and economic goals, in addition to being capable of meeting the regulatory requirements that National Pollutant Discharge Elimination System (NPDES) and other regulations have established in the past 10 years.

The use and implementation of LID in California will grow rapidly over the next several years and new data, studies, and approaches will continue to be developed. This review is designed to be a dynamic document that can be used and modified by a wide range of readers. The review is grouped into critical research areas and presented in four (4) sections. The four sections are as follows:

- **1.0 Introduction** – The introduction provides background on LID and presents the literature review objectives.
- **2.0 Literature Review Methods -** Section 2 discusses the methods for gathering references and the criterion for including them.
- **3.0 Findings and Gap Analysis -** The third section presents the literature findings and an interpretation of the trends and information gaps for each critical area.
- **4.0 Literature Review Matrix** - A literature review matrix has been provided so that users can quickly select and organize data that is relevant to their needs.
- **Appendices A and B** – The references are included in two lists, a bibliography and an annotated bibliography with the references grouped by critical area.

The study found that, while incomplete in scope, there is a sufficient amount of information available that communities can use to form a framework to develop LID stormwater programs. Much of the information that is included is from different climactic regions. The lessons learned and information from the studies, research papers, and websites are independent of local climate and geologic conditions and provide information that is required to integrate new and emerging strategies and techniques into municipal permit and watershed planning programs.

Assessing the current literature and data was the main focus of this effort, but equally critical is the identification of gaps in research and information. Knowing the deficiencies provides the opportunity for future research efforts to specifically target and address data gaps. **Table 1.1** includes all of the critical areas covered by the literature review and key information gaps for each. The information gaps are described in more detail in the Findings and Gap Analysis section.

Table 1.1 Information Gap Summary

Critical Area	Information Gaps
Design and Maintenance: *Bioretention*	Information on native/xeriscape vegetation for southern CA bioretention
	Performance and maintenance information on dry mulch cover for bioretention in southern CA (ie. organic vs. inorganic)
	Performance and modifications needed for influents with high pollutant loads
Filters	Field test for alternative media mixes to determine performance and operation
	Filter maintenance and operation costs for CA watersheds
Green Roofs	Green roof vegetation for southern CA conditions
	Green roof design for compliance with CA earthquake and fire safety codes
Infiltration Basins and Trenches	Zones where infiltration should be restricted (ie. identify safe distances from steep slopes, karst geology, or industrial zones)
	Effects of infiltration on engineered soils or fill
Landscaping	The quantitative stormwater benefits of xeric and LID landscaping
	LID landscaping guidance specific to southern CA
Permeable Pavement	Whole-life performance, maintenance, and operation in arid and semi-arid regions
	Performance comparisons among pavement types
	The feasibility of porous pavement for roadway or high traffic areas
Ponds, Wetlands, and Extended Detention Dry Ponds	Performance and operation of gravel based wetlands in southern CA
	Additional research and guidelines for dry detention basin retrofits and modifications
Rainwater Harvesting	Methods for optimal sizing of cisterns
	Air quality impacts on harvested stormwater
Site Planning	Strategies to make development watershed-oriented and protective of natural resources
Swales / Biofilters	Appropriate vegetation and necessary plant densities
	Landscape designs and public information that will change the public perception of swales
Vegetated Filter Strips and Riparian Buffers	Long term vegetated strip performance in arid conditions
Monitoring Methods	Monitoring strategies for BMPs with major modifications
	LID site monitoring to verify stormwater model results
Stormwater Modeling	Easy to use stormwater models
	Accurate and easily accessible local stormwater model input data
	Programming that better represents BMPs in stormwater models

Planning and Smart Growth	Comprehensive land use plans integrated with LID
	LID involvement in the early stages of site planning
Costs and Economics	Economic comparisons of conventional and LID sites in CA
	Triple bottom line analysis on LID projects
Training and Outreach Materials	LID training for plan reviewers and site inspectors
	LID outreach efforts linked with measurable water resource benefits
Pilot Projects	Expanding pilot programs
	Regional LID forum for stormwater managers
Institutional and program Development	Programs to promote green infrastructure
	Adapting innovative stormwater programs to southern CA
Regulatory	Hydromodification plans for new development and redevelopment for areas of CA not currently requiring them
	Urban retrofit programs for volume control
	LID incentive programs
Hydromodification	Hydromodification monitoring studies
	Appropriate hydromodification strategies

Of the most significant challenges and gaps in knowledge are how to integrate LID into land development planning and code enforcement programs, the long-term management of LID facilities, and how to determine the economic impacts and benefits of LID. Much of the literature to date has focused on individual BMPs which are only part of the design and management of LID projects and programs. There is limited data on the overall effectiveness of LID at the watershed scale and for emerging issues such as hydromodification. The development of protocols for the use of LID and conventional BMPs to address overall watershed planning and emerging issues is one of the key challenges where there is little guidance.

1.0 Introduction

1.1 Background

Conventional end of pipe systems of stormwater management have had limited success in achieving the positive stormwater outcomes that are required in the current regulatory environment. The failure of the conventional end of pipe systems to produce stormwater outcomes that are in compliance with current regulations led to the search for innovative solutions which were lower in cost to implement and maintain over the long term. Additional pressure on existing systems due to increased urbanization exacerbated the capacity problems of conventional systems.

Low Impact Development (LID) developed in response to the need for a better way to treat stormwater. The cross-disciplinary approach to stormwater management is an innovation in stormwater management practice. Stormwater management using LID may be designed as a team effort involving the skills of engineers, landscape architects, ecologists, horticulturists and planners. There are policy LID approaches and technical LID solutions. The design community, LEED® practitioners, social justice advocates and economic redevelopment specialists have a new interest in the arena of stormwater management as manifest through LID because of the multiple community and environmental benefits that are perceived to be likely from LID implementation.

LID is a site planning strategy that matches postdevelopment site hydrology with predevelopment hydrology or targets watershed resource protection goals and objectives and regulatory requirements (Prince Georges County, 1999). As described by the Prince George's County *Low-Impact Development Design Strategies*, LID consists of the following five (5) sequential steps. The first focuses on site inventory; the second and third steps consists of nonstructural LID design based on the inventory from the first step; the fourth step includes all of the structural elements of LID design; and the final step considers post-construction concerns:

1. **Preserve Sensitive or Critical Hydrologic Features** - In the early stages of site planning, the areas with important hydrologic functions, like streams, wetland, high-permeability soils, and steep slopes, must be identified. A layout scheme can then be devised that will integrate and preserve the function of these hydrologic features.

2. **Maintain Flow Timing** – Predevelopment flow paths must be maintained to the extent possible to help maintain runoff timing and flow duration. Disconnecting the flow of runoff from impervious areas, maintaining natural drainage, using open channel drainage, and avoiding construction of storm pipes and concrete channels all help to maintain flow timing.

3. **Minimize Site Development Impacts** – Reducing the percentage of impervious surfaces and disconnecting it from the storm sewer system will reduce the total surface runoff from a developed site. Specific site design techniques such as coving and clustering concentrate built areas in smaller land areas to permit greater size parcels to be left undisturbed; this is effective at the neighborhood scale of development. Construction sequencing of infrastructure and lot development is a strategy that may be employed to minimize exposed, unbuilt, or vegetated land areas compared to conventional development.

4. **Integrate Distributed Best Management Practices (BMPs)** - Distributed BMPs, such as bioretention, permeable pavement, infiltration trenches, and rainwater harvesting, will further reduce volumes and slow flow. These structural stormwater management practices can be designed and sited to meet specific watershed goals, nutrient capture, metals or hydrocarbon removal, volume reductions, or peak flow attenuation.

5. **Public Outreach for Pollution Prevention and BMP Maintenance** – Complete LID stormwater management practice will include property owner education on BMP maintenance as well as the traditional pollution prevention outreach.

All five (5) of the steps are required to create LID sites effective in achieving water quality and hydrologic objectives.

The vast majority of LID research, design work, pilot projects, and long term case study experience has been in the humid watersheds of the eastern US. While much of this information is useful and can be adapted to the semi-arid to arid climates of California, a wholesale application of eastern LID methods would be inappropriate. Southern California, San Joaquin Valley, and Sacramento Valley receive less than half the rainfall of eastern regions and have twice the evaporation rates. Furthermore, natural vegetation cover is sparse; erosion and sediment potential is generally greater due to soils with high erosion potential. Some BMPs designed for eastern climate conditions are likely to fail in this environment, while others will need major modifications.

1.2 Literature Review Objectives
The first objective of this literature review is to provide communities with readily available information that can be used to integrate LID into their resource protection and regulatory programs. This review effort evaluates how LID is currently being used, and its potential use to meet regional NPDES, TMDL, and SUSMP regulations and resource protection goals. The project team developed this information from literature and regulatory program reviews and input from resource and regulatory agencies and stakeholders.

The technical information from the literature review was evaluated with respect to existing regulatory programs, the state agencies that administer them, and existing state guidance to establish a gap analysis. Also, this analysis identified the prevailing climate conditions and its influence on LID performance and the selection of appropriate vegetation. The gaps in knowledge presented will need to be evaluated during pilot projects.

The methods for collecting and organizing research are covered in section 2. A summary of the findings and the gap analysis for each critical area are given in section 3. The fourth section consists of a literature review matrix that shows the critical research areas each reference covers. The matrix allows for an efficient search and comparing of references. All of the references are listed in a bibliography and in an annotated bibliography grouped by critical area in Appendix A and B, respectively.

2.0 Literature Review Methods

2.1 Critical Areas
This study sought to obtain the latest research and most complete picture of LID technology. The fourteen (14) critical areas of LID research covered by the review were selected by the TAC. The critical areas are:

- Design and Maintenance
- Monitoring Methods
- Stormwater Modeling and Sizing Tools
- Planning and Smart Growth
- Costs and Economics
- Manuals of Practice
- Training and Outreach Materials
- Pilot Projects
- Institutional and Program Development
- Stakeholder Effort
- Regulatory
- Resource Protection
- Hydromodification
- Ancillary Programs

2.2 Review Methods
Internet searches, journal databases, recent conferences, leading researchers and stormwater regulators were all queried for LID articles, resources, presentations, and transcripts.
Reports on LID studies completed and ongoing have been added up to the summer of 2007. Several criteria were used for determining whether an item would be included in the review. Geographically, California related LID literature was given highest priority and then articles from similar climate regions. Commonly referenced, reviewed, and comprehensive publications from the eastern U.S. body of LID literature were included. Many jurisdictions across the U.S. have developed manuals, fact sheets, and outreach materials on LID. Many of these materials have similar information. To avoid repetition, only a representative cross-section of these materials has been included.

Preference was also given to literature that is readily available. Many of the references include weblinks to the full text of the document or to an abstract. Over time, web links will need to be updated or removed. The review includes PowerPoint presentations from the 2007 2nd National Low Impact Development Conference. When the PowerPoints themselves are not helpful, contact information for the project researchers are usually provided for obtaining additional information.

3.0 Findings and Gap Analysis

3.1 Introduction

The gaps in the literature are primarily at the macro scale while micro scale research, such as the performance of specific BMPs in specific locations is available. Larger scale research, based on watershed functionality or hydromodification and adjunct impacts such as enhanced real estate values, improved habitat quality and increased community safety are largely anecdotal but occasionally documented. LID practice data is more readily available for wetter regimes, but data from Australia is also coming into the published realm. The approach to the LID research and the way data is collected varies, depending on the discipline that initiates the study. Stormwater has been the province of public work departments and most of the municipal studies in the US which were reviewed have been designed and directed by engineers; some studies are done in collaboration with landscape architects, ecologists, and economists. Most of the earlier work focuses on water quality and volume reductions; later studies evaluate the economic impacts and later applications focus on the amenity value that LID can add to a community.

3.2 General Findings

Changes in regulatory requirements and a new emphasis on site hydrology and function are increasing interest in LID within the state. The preliminary draft NPDES Construction General permit released by the SWRCB earlier in 2007 contains specific requirements for post-construction stormwater runoff and would establish state-wide standards if approved. As currently framed, the preliminary draft permit requires mitigating hydromodification by maintaining pre-development hydrologic characteristics on a site. The intent is also to designate approved post-construction BMPs that include minimizing site disturbance and impervious surfaces; treating stormwater with infiltration, retention/detention, and biofiltration; and ensuring the disconnectivity of interior drains; all of which are LID practices.

Several RWQCBs have implemented hydromodification management plans (HMPs) that focus on a site's natural ability to manage rainfall. These plans generally require that stormwater discharges be managed to limit erosion and siltation effects from increased peak flow and runoff volume. Under these guidelines post-construction runoff is limited to pre-construction rates and/or durations and runoff erosion potentials. The preliminary draft permit and HMPs will require more robust stormwater management, and through the designated requirements, will encourage the increased application of LID practices and techniques. These programs will have a significant impact on the greenfield development and redevelopment conditions to which they apply.

LID also has applications for existing developments and urbanized lands subject to future regulations to address the significant pollution impact largely due to the developed landscape and its associated runoff characteristics. Total Maximum Daily Load (TMDL) requirements and other water quality criteria that may be implemented will necessarily require reductions in stormwater pollution. The dual benefit of reducing stormwater volume and improving water quality with LID practices allow for needed pollutant load reductions to improve water quality.

The versatility of LID will make it an attractive compliance option for current and emerging regulations and has implementation opportunities for new development and retrofit applications.

Some jurisdictions have been developing approaches to integrate LID into overall watershed and community development programs. For example, the Seattle Green Factor, Washington D.C. Anacostia redevelopment standards, and the Portland stormwater utility fee structure, are fairly well developed, but information about these LID programs has not been widely distributed. These approaches were designed to address Combined Sewer Overflow (CSO's), which are primarily concerned with reducing the volume of runoff at peak flow times to the drainage system. CSO control requires the reduction of runoff volume, which also reduces runoff energy to protect streams and aquatic resources and preserve infrastructure capacity in Southern California. The knowledge base for the integration of LID into quasi-regulatory or industry design standards, such as LEED, Smart Growth, or Context Sensitive Solutions, is also limited.

At the site planning level, progress is being made on evaluation techniques and software models for analyzing and comparing LID design strategies. This area of research will be critical to help regulators determine the effectiveness of LID and to give the design industry tools to analyze and design construction plans for LID sites. The hydromodification plans (HMPs) required by the San Francisco Bay RWQCB helped to initiate the Contra Costa BMP Sizing Tool and the Bay Area Hydrology Model (BAHM).

Development project economics are another major research growth area. Traditional cost analysis procedures for conventional BMPs are not directly applicable to LID. This is because the ability to value many of the potential benefits, such as green community or the ability to leverage resources, has not been fully developed by economists or is not being used by stormwater planners and designers.

3.3 Information Gaps by Critical Area

Summaries for each of the critical literature review areas are provided below. Each summary includes an overview of the topic and conclusions on the state-of-the-art and data gaps.

3.3.1 Design and Maintenance

The literature on the design of BMPs is extensive and dates back 20 years. However, the literature on the design of BMPs in the context of LID extends back no more than 10 years, and research specific to the semi-arid southern California climate dates back even less. Many of the most comprehensive BMP studies have been conducted by Caltrans. For the most part, the Caltrans pilot studies have found that the stormwater BMPs have the same pollutant removal efficiencies as those studied in other parts of the US. The CASQA BMP Handbooks provides brief summaries of the California experience with individual BMPs.

Several resources contained comprehensive surveys of information on individual BMPs. A couple of those resources are noted here. The International Stormwater Best Management Practices Database provides standardized information on the performance of roughly 200 BMPs. The database is funded and maintained by a group of sponsors including the American Society of Civil Engineers (ASCE) and the USEPA. The website for the database, www.bmpdatabase.org, contains protocols for monitoring, evaluation, and reporting of BMPs (ASCE, n.d.). A comprehensive literature review for 11 BMP types, not specific to California, can be found in the 2004 Water Environment Research Foundation report on *Post-Project Monitoring of BMPs/SUDS to Determine Performance and Whole-Life Costs* (WERF, 2004). The 11 BMP types studied by WERF are:

- Dry extended detention basins
- Wet ponds
- Infiltration basins
- Infiltration trenches and soakaways
- Retention/irrigation systems
- Vegetated swales
- Vegetated buffer strips
- Sand an organic filters
- Water quality inlets and oil/water separators
- Bioretention areas
- Porous and permeable pavement

After a review of 243 publications from the US and UK, the report authors identified research needs and data gaps for each of the BMP types in the areas of siting, design, performance, construction, costs, and maintenance. This literature review contains many, but not all of the references contained in the WERF literature review. The WERF literature review is a good place to find research gap information for the previously mentioned BMPs. The research gaps described below build on those identified by WERF.

BMP and site design strategies applied in the humid eastern watersheds must be adapted for use in California. Likewise, these strategies will need to be adapted within the diverse environments of California. Deb Caraco and T. Schueler provide a helpful starting place when choosing a stormwater practice for an arid or semi-arid watershed (Caraco & Schueler, 1999). Their recommendations are listed in **Table 1.2**.

Table 1.2. Design Modifications for Stormwater Practices in Arid and Semi-Arid Watersheds *(Source: Caraco and Schueler, 1999)*

Stormwater Practice	Arid Watershed	Semi-Arid Watershed
ED Dry Ponds	PREFERRED • Multiple storm ED • Stable pilot channels • “dry” forebay	ACCEPTABLE • Dry or wet forebay needed
Wet Ponds	NOT RECOMMENDED • Evaporation rates are too high to maintain a normal pool • Without extensive use of scarce water	LIMITED USE • Liners to prevent water loss • Require water balance analysis design for a variable rather than permanent normal pool • Use water sources such as AC condensate for pool • Aeration unit to prevent stagnation
Stormwater Wetlands	NOT RECOMMENDED • Evaporation rates too great to maintain wetland plants	LIMITED USE • Require supplemental water • Submerged gravel wetlands can help reduce water loss
Sand Filters	PREFERRED • Requires greater pretreatment • Exclude pervious areas	PREFERRED • Refer to City of Austin, Environmental Criteria Manual: Guidelines for BMP Design
Bioretention	MAJOR MODIFICATION • No irrigation • Better pretreatment • Treat no pervious area • Xeriscape plants or no plants • Replace mulch with gravel	MAJOR MODIFICATION • Use runoff to supplement irrigation • Use xeriscaping plants • Avoid trees • Replace mulch with gravel
Rooftop Infiltration	PREFERRED • Dry well design for recharge of residential rooftops	PREFERRED • Recharge rooftop runoff on-site unless the land use is a hotspot

Infiltration	MAJOR MODIFICATION • No recharge for hotspot land uses • Treat no pervious area • Multiple pretreatment • Soil limitations	MAJOR MODIFICATION • No recharge for hotspot land uses • Treat no previous area • Multiple pretreatment
Swales	NOT RECOMMENDED • Not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	LIMITED USE • Limited use unless irrigated • Rock berms and grade control essential to prevent erosion in open channels

For each of the BMPs covered by the literature review, research areas that need investigating are noted below for each BMP.

3.3.1.2 Bioretention

Bioretention is an emerging management practice. It has been most commonly associated with LID and was the basis for the development of the LID water balance approach that uses the soil and vegetation complex to treat stormwater. There have been a significant number of research projects in the past fifteen (15) years that have provided a great deal of information about their design, performance, maintenance, and cost. Unfortunately, this review found no research projects specific to bioretention cells in California. However, there are examples of working bioretention projects in California that have not been thoroughly studied, such as the bioretention cells used in the parking lot landscaped areas at a restaurant in Oakland, CA (**Fig. 1.1)**. Caltrans landscape architecture program is set to publish the results in 2007 of their Scoping and Siting of Ornamental Biostrips and Bioswales for Stormwater Treatment.

Figure 1.1 Bioretention Cells in Parking Lot Landscaped Areas *(Source: Low Impact Development Center)*

Bioretention research gaps specific to California are listed below.

- **Information on native/xeriscape vegetation for California bioretention -** Plant lists of xeriscape, California native, or semi-arid/arid vegetation effective for bioretention could not be found. The California LID manuals, like CASQA, City of Emeryville, and City of Salinas manuals, provide limited guidance on bioretention vegetation, such as natives that can withstand the inundation and dry cycles of bioretention. The California Native Plant Society provides a manual of California vegetation. A list of suitable plants and planting patterns would greatly aid homeowners and small project developers to implement bioretention. California vegetation should be studied for their hardiness, maintenance requirements, treatment capability, and ability to aerate soil media under the conditions of bioretention. Trials could be established in cooperation with the University of California either through the Kearney Foundation of Soil Science at UC Berkeley, or UC Riverside US Salinity Lab. Similarly, the CSU Sacramento Campus Water Research Group would have the capability to work with pilot projects; both of these groups are engineers but should work with the plant sciences expertise within the university or community to achieve the range of expertise required for a true evaluation.

- **Performance and maintenance information mulch cover for southern California, such as organic vs. inorganic** – Eastern stormwater manuals and the CASQA manual recommend at least a few inches of mulch cover for bioretention. The mulch layer is where much of the stormwater treatment occurs. Many planting guides in dry climates recommend a thick layer of mulch to retain soil moisture. Mulch that is used in the East is typically double ground hardwood mulch. In Western applications, a different form of mulch, less mulch, or no mulch may be the appropriate solution. A mulch layer may represent a fire hazard in dry seasons or look incompatible with xeriscape. The Caraco and Schueler (1999) article suggests gravel as mulch. Performance data and operational issues with using gravel cover would be helpful. If organic mulch is used, guidance on the ideal types of commonly available southern California mulch would be helpful.

- **Performance and modifications for influents with high pollutant loads** – Bioretention in arid and semi-arid regions are likely to need additional pretreatment due to flows with higher pollutant concentrations. The performance of bioretention in the southwest might be different then in the east where much of the bioretention research has been done. Salinity is a key concern in southern California soils.

Figure 1.2. Sand Filter at the City of Sacramento Engineering Services Bldg *(Source: U of California, Davis)*

3.3.1.2 Filters

Filters are another BMP with a large volume of research and operational experience behind them. They come in many configurations and media types, but the most common filter in use is the Austin Sand Filter. Sand filters had their beginnings in Austin, TX and are now used all over the country. Typical features of Austin sand filters are a bypass chamber, sedimentation chamber, flow distribution cell, and a sand filter bed. Austin Sand filters are being used in five (5) Caltrans retrofit projects. The D.C. and Delaware filters are two other common filter types for use in ultra-urban settings. Since filters do not require a constant supply of water or need to be vegetation, although they can be vegetated, they work well in dry climates.

- **Field tests for alternative media mixes to determine performance and operation** – Studies of sand filters have consistently shown high removals of suspended solids, but removals of soluble pollutants and especially nutrients are mixed to low. Studies of media mixes in laboratory settings have been conducted to determine their ability to remove soluble pollutants and nutrients, (Clark & Pitt, 1999). There is little data on field application of alternative filter mediums that may have better nutrient or soluble pollutant removal.

- **Maintenance and operation costs for California watersheds –** More rigorous pretreatment might be necessary for the higher sediment loads expected from arid and semi-arid runoff. This may require more frequent monitoring, maintenance, and filter media replacement.

3.3.1.3 Green Roofs

Many cities in the US and in Europe are generating literature on green roofs. Certain characteristics of the California climate and building and fire code make green roof design in California particularly challenging. Currently, there are only a few examples of green roofs in California. There are two commonly cited examples of California green roofs, the green roof of Premier Automotive Group in Irvine, CA (**Fig. 1.3)** and the green roof of GAP Inc. in San Bruno, CA. In 2006, the City of Los Angeles posted a detailed guide on green roof design in Southern California and the challenges that set this region apart from other cities actively promoting green roofs, like Portland and Chicago. A couple of those challenges and areas of needed research are identified below:

- **Green roof vegetation for California climates –** Existing lists of appropriate green roof plants are for areas receiving significantly more precipitation than most parts of California. Of the common green roof plant characteristics, drought tolerance and fire resistance are particularly emphasized for California.

- **Green roof design for compliance with California earthquake and fire safety code** – California communities desiring green roofs will need to review their building codes and assess what criteria green roofs would need to meet, especially in regards to earthquake loading and fire safety.

Fig. 1.3 Green roof on North American Headquarters of Premier Automotive, Inc. Irvine, CA. *(Source: Roofscapes, Inc.)*

3.3.1.4 Infiltration Basins and Trenches

California has had extensive practice with infiltration devices. The large infiltration basins in Fresno, CA are a frequently cited successful application. The Fresno infiltration basins have been in place since the 1960s and have not posed a threat to groundwater quality. Village Homes in Davis, CA also demonstrated successful long term use of infiltration basins on a smaller scale. In Caltran studies, the primary reason for infiltration devices failing were poor soil permeability and a high groundwater table.

- **Zones where infiltration should be restricted –** LID ordinances and codes typically place restrictions on infiltration in areas with karst geology, industrial runoff, and near steep slopes. Local jurisdictions should identify areas where infiltration should be limited or prohibited. Additional research is needed to determine the appropriate safe distance infiltration should occur from steep slopes to mitigate the danger of landslides.

- **Effects of infiltration on engineered soils –** Most construction in California is on engineered fill or cut areas with recompacted material that may have a high shrink or swell potential. Geotechnical practices call for maintaining a dry subgrade, and the migration of infiltrated water in hillside developments in select backfill areas (such as adjacent to utilities) has not been studied.

3.3.1.5 Landscaping

Sustainable landscaping has been promoted by water utilities all over the Southwest. Consequently, the focus of research on xeric landscaping in the Southwest has been on water savings from reduced irrigation. The literature in this section includes one article on the water and maintenance savings of native arid landscaping (Sovocool & Rosales, n.d.) while the other publications contain a mix of landscaping design, establishment, and qualitative benefits. Beyond plants, LID landscaping includes preserving native soil structure, maintaining or creating micro topography, and allowing runoff from impervious surface to flow into landscaped areas. The John T. Lyle Center for Regenerative Studies at Cal Poly Pomona has a mission to advance the principles of environmentally sustainable living. The center is in the early stages of the water systems and ecological context components of their demonstration projects. Caltrans Landscape Architecture Research program publishes sustainable landscaping research from UC Davis. The program identified four major California studies to be available beginning in 2008. These studies are evaluating compost and other measures for erosion control and effects of reduced moisture during plant establishment.

- **The quantitative stormwater benefits of xeric and LID landscaping** – There is an opportunity for local research projects to quantify not just water consumption savings, but also runoff treatment and reduction. One such project, an undertaking of University of California Cooperative Extension, has just begun (Brennan, 2007). The Extension constructed three mock homes, one with conventional turf landscaping, one to represent a retrofitted home, and another to represent a low impact home.

- **LID landscaping guidance specific to Southern California** – Many comprehensive LID manuals from the East Coast and Northwest include guidance on landscaping. An LID landscaping guide specific to southern California which includes not only suggestions on plantings but also information on appropriate mulches, soil amendments, and grading would be beneficial.

3.3.1.6 Permeable Pavement

There are many long term permeable pavement and paver pilot projects ongoing around the country. Permeable pavements have many advantages. Aside from reducing runoff volumes through infiltration, studies are showing considerable flow attenuation and water quality benefits. They may also prove to be cooler as the body of literature on cool pavements suggests is the case.

Figure 1.4. Permeable Paver Lot at the Washington Navy Yard
(Source: Low Impact Development Center)

Most research needs for permeable pavement have to do with long term issues. A couple of these gap areas are listed below:

- **Whole-life performance, maintenance, and operation in arid and semi-arid regions** – The life performance and maintenance of permeable pavements in California may be different from those of other regions, because of longer pollutant build-up periods and runoff with higher sediment loads.

- **Performance comparisons among pavement types** – All permeable pavement types may not function equally. Some may have a tendency to clog earlier or are less capable of removing runoff pollutants. Long term side by side case studies will be helpful in parsing out the differences, such as the ongoing study being conducted by the University of North Carolina in Kinston, NC (Collins et. al., 2007).

- **The feasibility of porous pavement for roadway or high traffic areas** – Due to concerns of clogging, compaction, and structural stability, permeable pavements for roadways and high traffic areas have been generally discouraged. For over 20 years have used porous open-graded asphalt for the friction course on highways for durability and to reduce hydroplaning and noise. The literature review found one US study on a fully porous asphalt structure used on a highway. A porous asphalt section of Arizona State Route 87 had an initial permeability of 100 in/hr and after five years of heavy traffic, the permeability was 28 in/hr. The section showed no cracking or significant deformation (Hossain et al., 1992). Long term pilot studies would help optimize high traffic permeable pavement design. Considering the impervious area streets and highways add to urbanized areas, a durable, reliable, and low maintenance permeable pavement structure for high traffic roads would make a significant impact on stormwater runoff volumes, peaks, and pollutant loads.

3.3.1.7 Ponds, Wetlands, and Extended Detention Dry Ponds

Ponds, wetlands, and extended detention dry ponds are all considered centralized site treatment options. The focus of LID is on upland decentralized stormwater controls, but under certain site circumstances a “pocket” pond or wetland may be used. The use of ponds and wetlands on Southern California sites will be extremely limited because of the lack of consistent base or surface flow that can be used to maintain critical hydrology.

- **Performance and operation of gravel based wetlands –** Stormwater wetlands filled with gravel might be viable in arid or semi-arid climates. A constructed gravel-based stormwater wetland in Phoenix, AZ has been successful in treating parking lot runoff. The gravel has reduced evaporation enough to limit the amount of supplemental water required (Fox and Wass, 1995). Additional performance and operational information needs to be collected on gravel based wetlands.

- **Additional research and guidelines for dry detention basin retrofits and modifications -** Dry detention ponds have been the most commonly used stormwater management practice in California, mainly for flood control. Research and guidelines for retrofitting and improving the dry detention design are needed. One such dry pond design modification is to include a dead storage area that remains dry except for during rainy periods. Caltrans is in the midst of a multi-year study of dry detention basin modifications. The project makes sizing, siting, and inlet and outlet alternative comparisons (Caltrans, 2006).

3.3.1.8 Rainwater Harvesting

Rainwater harvesting systems are the stormwater management practice with which humans have had the longest history. Little southern California regional information was found on rainwater harvesting. Despite a short lived tax credit in the early 1980s, rainwater harvesting systems are an underutilized stormwater BMP and water conservation measure in California. Much of the state-of-the-art in rainwater harvesting literature comes from Australia, an arid to semi-arid country. An estimated 1 million Australians use rainwater as a primary source of domestic water (Gould and Nissen-Petersen, 1999). In general, the design, maintenance, and performance of rainwater harvesting systems are well documented and understood.

Fig. 1.5 Rain barrel for student garden
(source: Low Impact Development Center)

The following areas of research would be helpful in encouraging this technology in California.

- **Methods for optimally sizing cisterns** – Cisterns or tanks are the most expensive component of a rainwater harvesting system. Simpler methods for determining an optimal tank size for a particular area would ease implementation. The optimization would be based on local rainfall patterns, catchment area, and a given demand. The result would allow a user to determine an adequate tank size based on a desired level of reliability.

- **Air quality impacts on harvested stormwater** – A study by the SCCWRP found substantial deposition of air pollutants in the watersheds of Los Angeles (Sabin et al., 2006). Even if no pollutant generating activity occurs in the catchment area, such as on a rooftop, atmospheric deposition could be contributing a pollutant load. The impacts of atmospheric deposition on the quality of harvested rainwater should be investigated. Certain pollutants in harvested rainwater would require restrictions on usage to non-potable uses and landscaping for unconsumed and low contact vegetation.

3.3.1.9 Site Planning

Rather than a BMP, site planning is a step in the LID design process. The principles of LID site planning will be the same in southern California as in east where LID was pioneered. Those principles are preserving the important hydrologic features such as riparian buffers and highly permeable soils, minimizing impervious area, disconnecting impervious areas, restricting ground disturbance, and increasing drainage flow paths. Many of the LID manuals describe the site planning procedure; the *Low-Impact Development Design Strategies Manual* by Prince George's County, MD is particularly helpful. One LID site planning concern specific to California is noted below:

- **Strategies to make development watershed-oriented and protective of natural resources** – A study by the SCCWRP found that the threshold of impervious cover for stream degradation or hydromodification is lower in southern California than in watersheds of wet climates. The Protection of California streams and natural resources will require different site planning guidelines from those drafted in other parts of the country.

3.3.1.10 Swales and Biofilters

A 1997 survey by the Center for Watershed Protection of stormwater managers in arid and semi-arid regions found a preference for and biofilters and swales over all others. There are many applications of vegetated swales in California. The Caltrans program has sited 6 biofiltration swales, but the most noted application of bioswales in California is in the Village Homes in Davis, CA (**Fig 1.6**). The swales running through Village Homes were constructed in the 1970s, are capable of infiltrating beyond the volume of the 10 year storm and have become a community amenity (Francis, 2003).

Figure 1.6. Swale in the Village Homes, Davis, CA.
(Source: University of California, Davis)

- **Appropriate vegetation and necessary plant densities for swales** – As with the bioretention, identification of optimal vegetation for different regions is needed. An investigation of minimum plant density is also necessary. Sparse vegetated cover in the swales will lead to erosion and channelization. Arid regions of California may not be able to maintain enough plant density without irrigation.

- **Landscape designs and public information that will change the public perception of swales** – In the 1970s, the Village Homes developers struggled to convince city engineers that swales would work just as well as subterranean storm sewers. This perception of swales being inferior to curb and gutter drainage still exists today. Village Homes and Seattle's S.E.A. Streets program have shown that swales can work in medium density land use and be attractively landscaped. More bioswale projects with contributions from landscape architects will raise awareness and appreciation for swales.

3.3.1.11 Vegetated Filter Strips, Vegetated Slopes, and Riparian Buffers

Vegetated filter strips, vegetated slopes, biofiltration strips, and riparian buffers all do essentially the same thing, slow runoff velocities, settle out sediments, and allow for some infiltration. Generally, these BMPs are used to treat small drainage areas and as pretreatment for other BMPs. Caltrans has completed a study of three biofiltration strips and has more ongoing studies. The strips did not need irrigation, even in areas receiving only 10 inches of rain a year. Caltrans found pollutant and volume reductions, and the most negative impact on performance came from the presence of gophers.

- **Long term vegetated strip performance in arid conditions** – Vegetation types and densities that can be maintained without irrigation in arid southern California need to be evaluated for performance. Another important aspect to study is the ability of the plants and soils to maintain removal rates over the long term.

3.3.2 Monitoring Methods

The references listed in the monitoring section provide a snapshot of citations documenting the effectiveness and monitoring methods related to baseline stormwater data and stormwater BMP performance. Most of the monitoring approaches have been based on conventional end-of-pipe peak flow or flow concentration criteria. LID is based on a water balance approach that requires continuous monitoring and evaluation of other hydrologic elements, such as evapotranspiration, field capacity, groundwater infiltration, and uptake of pollutants in order to determine the effectiveness of the practice.

The study of BMPs in a series and the effect of non-structural techniques are limited. The cumulative effect of the practices within a watershed has yet to be sufficiently quantified for the purposes of replication in different contexts. One of the apparent strengths of LID is its extreme flexibility in how it is configured. At the same time, that flexibility makes replication of results dependent on the skills of the practitioners of the method.

- **Monitoring strategies for BMPs with major modifications** – Many BMPs will require design modifications to function in the drier environments of CA. The performance adjustments, if any, from these modifications will need to be determined through monitoring.

- **LID site monitoring to verify stormwater model results –** To verify that the models are accurately simulating real world runoff and pollutant loads from the undeveloped, developed, and developed with LID sites. Currently, sites in Contra Costa using the BMP sizing tool are being monitored to ensure the regulatory goals are met.

3.3.3 Stormwater Modeling and Sizing Tools

The modeling of LID is necessary for the stormwater management approach to be accepted by regulators and developers. Models are needed to estimate pre-developed levels of peak flow, peak flow timing, runoff event frequency, runoff volume, and loadings of various pollutants. If the correct assumptions are made, and the models are used correctly, then models can verify whether an LID site plan will meet regulatory stormwater objectives. There are many urban stormwater models capable of modeling a few or many components of LID for hydrology, water quality or both. This review covers commonly used urban stormwater models that can be applied in California. This section also includes summaries of selected California stormwater modeling case studies.

In July 2006, the EPA published a study on modeling urban BMPs titled *BMP Modeling Concepts and Simulation*. **Table 1.3** is a modified version of an urban stormwater model summary table in the EPA study. The results from these software programs are in runoff volumes, storm peaks, or pollutant loads.

Sizing tools are another approach to BMP design. These tools simplify the LID design process for developers and engineers who are not proficient in modeling. The BMP sizes generated by the tools were determined by modeling a variety of site conditions and standardized BMP designs to meet given stormwater management goals. The results are in BMP sizes or required storage volumes. A list of these sizing tools and models used to develop them are in **Table 1.4**.

Table 1.3 Common Urban Stormwater Models and Regional California Stormwater Models

Model	Agency/Source	Hydrology/Hydraulic	Water Quality	Continuous Simulation/ Single Event
National Models				
EPA Stormwater Management Model (SWMM)	US EPA/OSU	Hydrology/ Hydraulic	Yes	CS/SE
Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8)	William W. Walker, Jr.	Hydrology	Yes	CS/SE
Hydrological Simulation Program-Fortran (HSPF)	US EPA	Hydrology	Yes	CS/SE
Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)	US EPA	Hydrology/ Hydraulic	Yes	CS
Source Loading & Management Model (SLAMM)	Robert Pitt	Hydrology	Yes	CS
Hydrologic Modeling System (HEC-HMS)	Hydrologic Engineering Center of the US Army Corp of Engineers	Hydrology/ Hydraulic	No	SE
Prince George's County BMP Model (PG BMP Model)	Prince George's County, Tetra Tech, Inc.	Hydrology	Yes	CS
Regional Models				
Bay Area Hydrology Model (BAHM) (based on HSPF)	Clear Creek Solutions, Inc., Santa Clara Cty, Alameda Cty, San Mateo Cty.	Hydrology	Yes	CS
XP Stormwater Management Model (XP-SWMM)	XP Software			
XP-STORM	XP Software, Los Angeles County	Hydrology	Yes	CS

Table 1.4 BMP Sizing Tools

Sizing Tool	Agency/Source	Model Used to Develop Tool	Continuous Simulation/ Single Events	Elements Sized
Basin Sizer	California State University Sacramento	STORM	CS	Infiltration basins, detention basins, and flow based BMPs
Bay Area Hydrology Model (BAHM)	Clear Creek Solutions, Inc., Santa Clara Cty, Alameda Cty, San Mateo Cty.	HSPF	CS	Storage tanks, Ponds, Wetlands, Biortention, Sand Filter, Swales, Infiltration Trench
CA Stormwater BMP Handbook Approach	Stormwater Quality Task Force	STORM	CS	Required Capture Volume
Contra Costa County IMP Sizing Calculator	Contra Costa Clean Water Program, Dan Cloak Environmental Consulting	HSPF	CS	Areas of Bioretention; Swales; Infiltration Planters; Flow-through Planters
National LID Manual Techniques	EPA, Prince George's County	TR-55	SE	Required Retention Volume Required Detention Volume
City of Emeryville Stormwater Sizing Worksheet	City of Emeryville		SE	Metered Detention, Bioretention, Planter Strip, Flow-Through Planter Box, Biofiltration,

There are many directions for research in the area of LID modeling. A few important areas are listed below:

- **Easy to use stormwater models** – Many of the best stormwater programs for modeling LID are complex and nuanced. Large developments can employ a skilled stormwater modeler, but the developers of more common small sites may not have the same capacity to prove compliance with water quality and hydromodification regulations. Simplified and user-friendly models will be essential for creating solutions which meet more restrictive stormwater regulations. The Contra Costa LID sizing tool and BAHM have shown progress in this direction. These tools are designed for a specific region and link the modeling and sizing with the local regulation requirements.

- **Accurate and easily accessible local stormwater model input data** – The simulations and output results are only as good as the input data that are put into the models. Continuous rainfall data is critical for analyzing stormwater management scenarios for water quality and hydromodification. Furthermore, rainfall data with small time steps, 15 min to 5 min, are needed for design accuracy. The California Department of Water Resources is a helpful resource for obtaining local rainfall data, but weather stations that collect small time step rainfall data over long continuous periods are few. Collecting and inputting accurate land related data, such as soils, area, and flow paths, is also difficult. Better GIS databases and GIS integration with stormwater models can ease this effort.

- **Programming that better represents BMPs in stormwater models** – None of the stormwater models can perfectly represent a stormwater BMP. Some stormwater models limit the modifications that can be made to a particular BMP type. BMP performance can vary due to regional differences, such as pollutant loading, vegetation, and rainfall patterns. Those differences need to be determined and reflected in the model's programming.

3.3.4 Planning and Smart Growth

LID must be integrated at all levels of development planning, small scale to large scale and from preliminary stages to post-construction. This section of the review includes information on LID planning approaches from around the world as well as several innovative approaches in southern California. Smart growth planning is often confused with LID, which is a site development method and not a land-use planning approach. While not exclusive to smart growth, LID can serve to compliment sustainable smart growth development.

- **Comprehensive land use plans integrated with LID** – The Green Visions Plan for 21st Century Southern California provides an exceptional model for incorporating LID into comprehensive landuse planning. By combining local GIS data sets, filling in information gaps, and using decision support tools, the Green Visions group was able to "nurture a living green matrix for southern California". These types of planning processes should be conducted in other southern California communities. The information from such studies will allow for the identification and protection of natural areas with hydrologic functions before new development, or they can help identify areas to be acquired and restored.

- **LID involvement in the early stages of site planning** – Often, by the time a development project reaches the point of permitting the development will have advanced too far to be redesign with a LID planning approach. Planning architects, landscape architects, and drainage engineers should begin a dialogue in the initial stages of site development so that the LID application is integrated into the development process. Otherwise, adding LID in the late stages of the design project will result in a retrofit design.

3.3.5 Institutional and Program Development

The institutions of California are well positioned to push LID into widespread use. The state of California has a well developed institutional framework that can aid the development of a comprehensive LID program.

- **Programs to promote green infrastructure -** LID fits into the larger picture of green infrastructure. Green infrastructure is a comprehensive ecological approach that balances urban development with the natural environment. Promoting the concept of green infrastructure with multiple benefits might be a better method for realizing widespread use of LID.

- **Adapting innovative stormwater programs to southern California –** The Seattle Green Factor is a landscaping requirement for commercial areas that stipulates that 30% of a site must be vegetated. The Green Factor gives credit for permeable pavement, green roofs, rainwater harvesting, and low water-use plants. This program could be adapted to southern California with a vegetated requirement and credits that make sense in the climate and development conditions of that region.

3.3.6 Cost and Economics

Installation costs for BMPs are fairly well established. Many BMPs, such as buffer strips, bioretention, and swales, will have similar construction and operational cost as compared to other typical landscaping features. Many of the research gaps identified for individual BMPs acknowledged the need for long term operational costs of maintenance and component replacement research and a comparison of those costs to conventional systems.

- **Economic comparisons of conventional and LID sites in California –** There have been studies comparing the economics, the capital and maintenance costs, of an overall site designed with LID compared to sites designed with conventional stormwater management. *Changing Cost Perceptions: An Analysis of Conservation Development* by the Conservation Research Institute is a good example from Illinois. These types of studies have been conducted in the Midwest, Mid-Atlantic, and Southeast regions but none in California.

- **Triple bottom line analysis on LID projects –** Triple bottom line cost analysis considers the social and environmental benefits as well as the economic benefits in decision making. LID design has many ancillary benefits beyond water, including aesthetics, air quality, and reducing the urban heat island effect. A triple bottom line analysis of LID would help to make the case for LID.

3.3.7 Training and Outreach Materials

There are organizations at local and regional levels across the country involved in non-point source pollution prevention outreach. Many of the government agencies and non-profits involved in this outreach have begun moving into the promotion of LID. Regions, such as the Chesapeake Bay, Puget Sound, and Great Lakes, are building a collection of LID outreach and workshop materials. The materials include manuals, brochures, websites, and traditional forms of advertising. Some are very simple grassroots campaigns, while others are using social marketing expertise. The three elements that shape outreach are the target audience, the message, and the media. In a project to develop LID outreach materials for government officials and staff, the Northern Virginia Regional Commission identified a list of considerations (Mull, 2005).

1. Levels of knowledge about stormwater runoff and LID will vary. Introductions to LID should start with the linkages between urbanization, runoff volume, and stormwater pollution.
2. There is a lot of LID information to cover. Discussions need to provide enough detail for officials to analyze future LID land use cases without being overly technical.
3. The target audience and message should determine the media used to convey information about LID.

The lack of knowledge, lack of acceptance, and misconceptions about LID are the greatest obstacles to widespread implementation. Outreach and training programs are the only ways to overcome these obstacles.

- **LID outreach efforts linked with measurable water resource benefits** – The consensus from the proceedings of the 2005 National Nonpoint Source and Stormwater Pollution Education Programs Conference was that there is a general lack of measurable results from outreach programs. LID outreach programs need to be linked with measurable benefits like implemented BMPs, well maintained LID, or water quality benefits.

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- **LID training for plan reviewers and site inspectors** – LID training programs will be crucial for public plan reviewers to understand the performance or BMPs and the models used to validate an LID management strategy. Just as important, site and building inspectors need to recognize BMPs and whether they are being constructed properly.

3.3.8 Pilot Projects

Many of the publications in this literature review describe pilot projects and real world applications of LID. The studies included in this section are specifically about pilot projects with rigorous monitoring.

- **Pilot programs** – The best way to encourage LID is to put more examples of this stormwater technology on the ground. Local examples will allow the development community to become more comfortable with LID and generate additional performance and operational experience.

- **Regional LID forum for stormwater managers** - A dialogue among southwestern stormwater managers on climate appropriate LID has begun. A forum for California stormwater managers to share pilot project and program experiences will help determine the optimal LID stormwater practices for these arid and semi-arid regions.

3.3.9 Regulatory

With the technical approach coming into focus, the regulatory system needed to foster and propel LID has not yet developed. Several states, including California, have begun to evaluate the regulatory changes that are required to mitigate urban non-point source pollution and hydromodification. This section reviews the federal, state, and local regulatory and the institutional structure that influences stormwater control in California. Various methods of incorporating LID requirements and incentives into regulations are included. The same approach will not work for every jurisdiction. Presented below are three suggested regulatory routes for communities to put LID into practice.

- **Methods for defining the benefits of LID that offset the end of pipe treatment requirements for new and re-development** – The SWQCB is currently drafting a new general post-construction runoff control permit which will include hydromodification requirements. Some California jurisdictions are already requiring hydromodification management plans (HMPs) such as those in the San Francisco Bay Region. Communities typically use a volume requirement to encourage LID in the HMPs. Using volume as the critical regulatory requirement instead of maximum flow rate leads to greater adoption of LID and vegetated systems. Methods are needed for defining the benefits of LID that will give new and re-development credit towards meeting regulatory goals. Local efforts to match regulatory compliance with LID have led to the Contra Costa County IMP Sizing Calculator and the Bay Area Hydrology Model. Modeling requirements may not be appropriate for development projects in areas of the state not covered by the SUSMPs and a credit system might be more appropriate.

- **Urban retrofit programs for volume control** – Many jurisdictions are already built-out and heavily urbanized and generate a tremendous amount of pollution and hydromodification. In most cases, matching the pre-development hydrology does not appear to be feasible because many urban areas lack land for stormwater controls and the natural hydrology has been significantly altered. Stormwater regulations in Portland and Washington have focused on volume retention requirements. The assessments and control requirements are structured differently to account for urban conditions.

- **LID incentive programs for California** – Incentive programs, while usually not as effective as regulatory requirements for widespread LID implementation, can encourage LID beyond the regulatory structure and reduce stormwater volume. For example, Portland, OR uses a stormwater utility fee based on a property's runoff volume; therefore, reducing site runoff will result in a recurring financial benefit.

3.3.10 Resource Protection
LID has taken hold more quickly in regions with critical water resources to protect such as the Chesapeake Bay, Puget Sound, and the Great Lakes. California has many water resource amenities to protect and restore. However, due to many factors, including the ephemeral stream, intermittent streams and hidden stormwater infrastructure, there is a disconnect among citizens between land activities and the quality of water resources. The publications in this section describe efforts to protect those resources from urban stormwater pollution.

3.3.11 Hydromodification
In addition to water pollution, urbanization impacts water resources through the processes of hydromodification, increased runoff volume, higher peak flows, and more frequent runoff events. The relationship between urbanization, the increase in watershed imperviousness, and receiving water impacts have been well documented (Bannerman and Weber, 2004) Stein and Zaleski, 2005). Conventional detention basins have been used to reduce peak flows but often exacerbate the problem of hydromodification. A Southern Coastal California Research Project (SCCWRP) study found hydromodification responses in California streams with watershed impervious covers between 3% and 5%. The publications in this section describe studies on how urbanization alters hydrology. The following are a couple recommendations made by the SCCWRP relating to hydromodification in southern California (Stein and Zaleski, 2005).

- **Hydromodification monitoring studies** – Monitoring programs need to be established on streams in undisturbed watersheds, streams subject to hydromodification, and streams with ongoing hydromodification management strategies. This monitoring will help to determine thresholds for hydromodification from urbanization and provide baseline data for identifying mitigation strategies.

- **Appropriate hydromodification strategies** – Further research needs to be done to determine the best hydromodification strategy based on channel type, setting, stage of channel adjustment, and amount of existing and expected impervious cover in drainage catchments. These strategies include LID methods, regional controls, in-stream controls, and restoration of degraded stream systems.

3.3.12 Ancillary Programs

Stormwater management does not happen in a vacuum. The way stormwater is managed is interrelated with many other environmental programs, including air quality, water supply, thermal, and environmental justice. The publications included here document the connections between stormwater and these other programs. LID fits into the larger picture of green infrastructure. Green infrastructure is a comprehensive ecological approach that balances urban development with the natural environment. LID stormwater benefits are accrued and the ancillary benefits may include improved property values, reduced crime rates and greater public health.

4.0 Literature Review Matrix

4.1 Literature Review Matrix Criterion

All of the publications reviewed meet more than one of the criterion areas. A literature review matrix was included to illustrate how the references relate to each other. The references are listed by section of the literature review, and then the primary and secondary subject areas are noted for each. The matrix will allow the user to identify helpful references for a single subject area or a group of subject areas. For instance, an engineer looking for guidance on bioretention cell design and California examples can scan the matrix for references meeting the criterion for California related, design, and case studies. Alternatively, the matrix also helps to identify information gaps. A description of each review criterion is provided below.

California Related

While an obvious criterion for this effort, the review focused on information and research tailored to California or West Coast climate, geology, resources issues, or management objectives. These articles may have been produced by State agencies or departments or may apply to institutional or programmatic elements of the State's management programs.

Design / Maintenance

The research on stormwater control design was intended to capture the more recent research conducted in semi-arid environments similar to many areas of California, characterized by relatively low annual rainfall totals, small individual events, and the predominant number of precipitation events occurring in winter. Caltrans data represented a significant portion of the available literature. Cross-referencing BMP performance data with other climatic regions was also of interest.

Monitoring / BMP Performance

Literature on monitoring methods was analyzed to determine its potential applicability to inform effective stormwater control and LID monitoring programs. A significant portion of this section will present case studies and field observations. Many of the references present monitoring results and BMP performance data. This information will present a historical perspective of semi-arid region monitoring methods and results and will be used to inform future monitoring recommendations.

Modeling

Modeling is critical for implementation and planning efforts. Literature on this topic was evaluated to determine which models or types of models have been used most successfully with LID BMPs. In addition, the complexity or ability or the model to handle multiple parameters was considered to adequately demonstrate the performance of an LID approach. Models commonly used in California and in the Western U.S. were also analyzed.

Planning / Smart Growth

LID and green infrastructure stormwater management approaches are greatly influenced by the planning process. Efficient water resource management will need to maximize the opportunities that are available during development and redevelopment. As an integrated, distributed stormwater control approach, LID optimally needs to be considered much earlier in the planning process than conventional stormwater approaches. Articles and information demonstrating how planning approaches have been used successfully in concert with LID or to advance the use of LID are included.

Cost / Economics

The cost of installing and maintaining stormwater BMPs is a significant driver in their selection. However, these costs, while important, are one facet of how LID costs should be considered. Because of their design and amenity benefits, LID BMPs can be a more cost effective stormwater management alternative. The referenced articles contrast conventional stormwater approaches with LID and also explore alternative methodologies of analysis.

Case Studies

Case studies are reviewed to provide practical examples of successful LID applications, regulatory initiatives, or modeling outputs. West coast examples were sought and given preference within the report. Consideration was given to case studies that highlighted climatic and regional influences on stormwater control and those that contained illustrative programmatic elements.

Training / Outreach / Stakeholder Efforts

This review investigated various outreach and training efforts that have been conducted by municipalities or outside actors. Most training materials are intended for federal or state officials but some are developed for local volunteer organizations. Materials generally include basic background information including stormwater's impact on water quality, practices that contribute or mitigate runoff, and existing programs.

Regulatory

Regulations enormously influence the efficacy and effectiveness of stormwater programs. California regulations were analyzed to determine their support of or limitation to increased LID use. Recent regulatory changes at the state and regional level were evaluated. Various regulatory approaches to stormwater management were reviewed from around the country along with their success and supporting LID implementation.

Resource Protection

LID programs and effective stormwater management are intended to lead to enhanced resource management and protection. Studies were evaluated to determine how LID acts as an integrated approach to enhance natural resources and how it can be used to satisfy natural resource protection requirements beyond stormwater control.

Water Quality

Monitoring and modeling data were reviewed to quantify the performance of LID practices and compare the results to conventional treatment practices. LID applications in arid climates were highlighted as well as studies that evaluated pollutants of concern in coastal California. Water quality performance of BMPs is often a critical evaluation criterion for many jurisdictions within the State.

Hydromodification

The latest requirements from the state and some regions have focused on how development and changes in land cover contribute to hydromodification. LID has a unique potential to satisfy regulatory requirements to limit hydromodification and maintain pre-development water balance. Studies were reviewed to demonstrate the use of LID to limit disturbances to site hydrology and provide representative treatment train approaches.

Water Cycle

The review for this category sought to include material that addressed how LID can be used as a comprehensive water management approach beyond addressing solely stormwater control. LID applications present the potential for reducing demand for potable water and inflow into wastewater treatment plants. As an integrated approach, LID can transcend the artificial compartments that generally define water management and contribute to a more economically and environmentally efficient systems approach.

A filled dot, ●, indicates the criterion is a primary topic of the reference. A partially filled dot, ⦿, indicates the criterion is a secondary topic or contains some useful related information in the reference.

4.2 Literature Review Matrix

Ref#	Title	Source	California Related	Design / Maintenance	Monitoring / BMP Performance	Modeling	Planning/Smart Growth	Cost / Economics	Case Studies	Training/Outreach/ Stakeholder Efforts	Regulatory	Resource Protection	Water Quality	Hydromodification	Water Cycle
	Design: General Design and Introductions to LID														
1.1.1	Protecting Water Quality in Development Projects: A Guidebook of Post-Construction BMP Examples	Alameda Countywide Clean Water Program	●	●					●						
1.1.2	Start at the Source: Design Guidance Manual for Stormwater Quality Protection	Bay Area Stormwater Mgt. Agency Assc.	●	●			⦿		●				●	⦿	
1.1.3	Methodology and Evaluation Tool for Comparing Post-Construction Stormwater BMPs	Bitting, J.	●	●					⦿				⦿	⦿	
1.1.4.	California Stormwater BMP Handbook: New Development and Redevelopment	CASQA	●	●			⦿	●			●		⦿	⦿	
1.1.5	CA BMP Maintenance Fact Sheets	CASQA	●	●											
1.1.6	Caltrans Treatment BMP Technology Report	Caltrans	●	●					●				●		
1.1.7	BMP Retrofit Pilot Program	Caltrans	●	●					●				●		
1.1.8	Stormwater Monitoring and BMP Development Status	Caltrans	●	●	●				●						
1.1.9	Stormwater Strategies for Arid and Semi-Arid Watersheds	Caraco, D. & T. Schueler	●	●					●				●	●	
1.1.10	Critical Components for Successful Planning, Design, Construction, and Maintenance of Stormwater Best Management Pracices	Claytor, Jr., Richard A.		●			●		●						
1.1.11	Low Impact Development Design: A New Paradigm for Stormwater Management Mimicking and Restoring the Natural Hydrologic Regime	Coffman, Larry S.		●									⦿		
1.1.12	New Low Impact Design: Site Planning and Design Techniques for Stormwater Management in Revolutionary Idea in Planning	Coffman, L. S.; Clar, M. L. & Weinstein, N.		●								⦿			
1.1.13	Narrow Streets Database	Cohen, A. B.		●											
1.1.14	Clearing and Grading: Strategies for Urban Watersheds	Corish, K		●									●		
1.1.15	Low Impact Urban Design and Development: Making it Mainstream	Eason, C.; Pandey, S.; Feeney, C.; Dixon, J.		●					⦿				●		
1.1.16	Stormwater Infiltration	Ferguson, Bruce K.		●											●
1.1.17	Northern San Francisco Bay Area Site Design Guidebook	Friends of San Francisco Bay Estuary	●	●					●						

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1.1.18	Achieving Sustainable Site Design through Low Impact Development Practice	Guillette, Anne	◉	●					◉		◉				
1.1.19	Low Impact Development: Lot Level Approaches to Stormwater Management are Gaining Ground	Hager, M. C.		●					●						
1.1.20	Let That Soak In: Breaking Ground with Low Impact Development Methods	Kane, B. P.		●											
1.1.21	Stormwater Mitigation for Architects and Developers	Lemus, Judith D. et al.	●	●					●						
1.1.22	Watergardens as Stormwater Infrastructure in Portland	Liptan, T. & Murase, R.		●	●				●				◉	◉	
1.1.23	Introduction to Low Impact Development	Low Impact Development Center, Inc.		●				◉							
1.1.24	Low Impact Development for Big Box Retailers	Low Impact Development Center, Inc.		●			●		●						
1.1.25	Managing Mosquitoes in Stormwater Treatment Devices	Metzger, Marco E.		●											
1.1.26	Chapter 12: Low Impact Development	Natural Resource Defense Council		●					●		◉				
1.1.27	A High-Density, LID with Infiltration in a Limestone Area: The Village at Springbrook Farms	Potts, A; Adams, M. & Cahill, T.		●					●					◉	
1.1.28	Low Impact Parking Lot Design Reduces Runoff and Pollutant Loads: Annual Report #1	Rushton, B.		●					●				●	●	
1.1.29	Developments Protecting Water Quality: A Guidebook of Site Design Examples (San Mateo County)	San Mateo Countywide Stormwater PP Program	●	●					●						
1.1.30	Developments Protecting Water Quality: A Guidebook of Site Design Examples (Santa Clara Valley)	Santa Clara Valley Urban Runoff PP Program	●	●					●						
1.1.31	Green Visions Plan for 21st Century Southern CA: 11. BMPs for the treatment of Stormwater Runoff	Sayre, J. M.; Devinny, J. S. & Wilson, J. P.	●	●					●				●		
1.1.32	Site Planning for Urban Stream Protection	Schueler, Thomas		●										●	
1.1.33	Better Site Design Fact Sheets: Green Parking, Alt. Pavers, Alt. Turnarounds, Narrow Res. Streets…	Stormwater Manager's Resource Center		●				◉					◉		
1.1.34	Stormwater Management Fact Sheets: Porous Pavement, Infiltration Basin, Bioretention, Infiltration Trench, Grassed Filter Strip, Wet Pond…	Stormwater Manager's Resource Center		●				◉					◉		

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1.1.35	Stormwater: Best Management Practices including Detention	Urbonas, B. R. & Stahre, P.		●											
1.1.36	BMP Fact Sheets	US EPA		●				⦿					⦿		
1.1.37	Performance and Whole Life Costs of BMP and Sustainable Urban Drainage Systems	Woods-Ballard, Bridget		●							⦿		●		
1.1.38	Parking Lot BMP Manual	Woodward-Clyde		●											
1.1.39	Particle Size Distribution in Highway Runoff	Yingxia, Li	●	●	●								●		
	Design: Bioretention														
1.2.1	Bioretention: An Efficient, Cost Effective Stormwater Management Practices	Coffman, L. S. & Winogradoff, D. A.		●				⦿					⦿		
1.2.2	Design and Construction of Bioretention Cells in Grove, Oklahoma	Chavez, R. A.; Brown, G. O.; & Storm, D. E.		●	●								⦿		
1.2.3	Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics	Davis, A.; Shokouhian, M.; Sharma, H. & Minami, C.		●									●	●	
1.2.4	A Field Evaluation of Rain Garden Flow and Pollutant Treatment	Dietz, M. E. & Clausen, J. C.		●									●	●	
1.2.5	Developing a Standard & Specification for Bioretention Soil Media: A Delaware Perspective	Greer, Randell		●									●		
1.2.6	Evaluation Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina	Hunt, W. F.		●	⦿										
1.2.7	Design Implications on Bioretention Performance as a Stormwater BMP: Water Quality and Quantity	Hunt, W. F. & Sharkey, L. J.		●									●	⦿	
1.2.8	Evaluation and Optimization of Bioretention Media for Treatment of Urban Stormwater Runoff	Hsieh, Chi-Hsu & Davis, Allen		●									●		
1.2.9	Characterization of Metal Accumulation in Bioretention Media	Jones, P. S. & Davis, A. P.		●	⦿										
1.2.10	Engineered Bioretention for Removal of Nitrate from Stormwater Runoff	Kim, H.; Seagran, E. & Davis, A.		●									●		
1.2.11	Reducing Combined Sewer Overflows Using Cisterns and Rain Gardens	Lancaster, Alice		●		⦿		⦿	●		⦿		⦿	⦿	

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1.2.12	Compost as a Soil Amendment for Water Quality Treatment Facilities	Lenhart, J. H.		●									●		
1.2.13	Burnsville Stormwater Retrofit Study	Leuthold, K.; Yetka, L. & Rozumalski, F.		●	⦿				●					●	
1.2.14	City of Lansing, Use of Bioretention in an Ultra-Urban Setting	Thomas, M.; Christian, D.; & Gamble, C.		●			⦿	⦿	●						
	Design: Filters														
1.3.1	Low Tech Filtration System Uses Leaves to Remove Solids	Anonymous		●									●		
1.3.3	Design of Stormwater Filtering Systems	Claytor R.&Schueler R.		●									●		
1.3.4	Optimization of Stormwater Filtration at the Urban/Watershed Interface	Hipp, J.; Ogunseitan, O; Lejano, R & Smith S	●	●					●				●		
1.3.5	Field Evaluation of Low Impact Development Practices for Treatment of Highway Runoff in an Ultra Urban Area	Prandhan, A. U.		●					●				●		
	Design: Green Roofs														
1.4.1	Fire & Wind on Extensive Green Roofs	Breuning, Jörg		●											
1.4.2	Extensive Roof Design and Implementation in Auckland, New Zealand	Fassman, A.; Simcock, R. & Mountfort, C.		●	⦿				●					⦿	
1.4.3	Selecting the Proper Components for a Green Roof Growing Media	Friedrich, C.		●					⦿						
1.4.4	The Green Roof Infrastructure Monitor	Green Roofs for Healthy Cities		●	●				●						
1.4.5	Using Green Roofs and Other BMPs to Reduce the Need for Stormwater Retention Capacity Requirements	Hilten, R. N. & Lawerence, T. M.		●	●									●	
1.4.6	Green Roofs: The Last Urban Frontier	Kiers, Haven		●											
1.4.7	EcoRoofs – A More Sustainable Infrastructure	Liptan, T. & Strecker, E		●	●			⦿					●	●	
1.4.8	Selecting a Green Roof Media to Minimize Pollutant Loading in Roof Runoff	Long, B.; Clark, S. E.; Baker, K & Berghage R		●									●		
1.4.9	Green Roofs – Cooling Los Angeles, A Resource Guide, III-9	Environmental Affairs Dept., City of LA	●	●							⦿				
1.4.10	Ecoroofs: Question & Answers	City of Portland, OR		●					⦿		⦿				

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1.4.11	Green Roofs, Stormwater Management from the Top Down	Scholz-Barth, K.		●				◉							
1.4.12	Green Walls 101: Introduction to Systems & Design	Sharp, Randy		●											
Design: Infiltration Basins and Trenches															
1.5.1	Digest 365: Soakaway Design	BRE		●					●						
1.5.2	Constructing an Infiltration Trench Retrofit BMP	Emerson, C & Traver R		●	●				●						
Design: Landscaping															
1.6.1	The Benefits of Trees	Alsentzer, U & Kenny J		●				●					◉		
1.6.2	Native Shrub Germination Relative to Compost	Caltrans	●	●				◉					◉	◉	
1.6.3	Synthetic Turf Demonstration Sites	Clean Water Newport	●	●				◉	●						◉
1.6.4	Abriculture: Integrated Management of Landscape Trees, Shrubs and Vines	Harris, Richard W.		●	●										
1.6.5	Care & Maintenance of Southern California Native Plant Gardens	O'Brien, B.; Landis, B.; & Mackey, E.	●	●						●					
1.6.6	A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert.	Sovocool, K.; Rosales, J. & Southern Nevada Water Authority	●	●	●										●
Design: Permeable Pavement															
1.7.1	The University of Washington Permeable Pavement Demonstration Project: Background & Field Results	Booth, D.; Leavitt, J. & Peterson, K.		●	●										
1.7.2	Streets Take Soaking at Green Development	Casper, B.	●	●	●				●						
1.7.3	Evaluation of Various Types of Permeable Pavements with Respect to Water Quality Improvement and Flood Control	Collins, K; Hunt, W. & Hathaway, J.		●	●										
1.7.4	Exfiltration from Pervious Concrete into a Compacted Clay Soil	Dobbs, P.; Wright, W. & Tyner, J.		●	●										
1.7.5	Permeable Pavement Performance for use in Active Roadway in Auckland, New Zealand	Fassman, E. & Blackbourn, S.		●											
1.7.6	Porous Pavement	Ferguson, B.	●	●	●			●	●				●	●	●
1.7.7	Dry Parking	Hansen, K.		●											
1.7.8	Porous Asphalt Pavement: The Whole Story – Construction, Performance, Maintenance, and Myth	Houle, J; Ballerstero, T; Roseen, R & Briggs, J		●	●									●	

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1.7.9	Porous Pavement for control of highway runoff in AZ	Hossain, M.; Scofield, L.		●	●				●						
1.7.10	Advances in Porous Pavement	Hun-Dorris, T.		●	●				●				⦿	⦿	
1.7.11	Use of Permeable, Reservoir Pavement Construction for Stormwater Treatment and Storage for Re-use	Pratt, C. J.		●											●
1.7.12	The Trickle-Down Effect	Sicaras, K.		●	●			⦿	●					⦿	
1.7.13	Permeable Interlocking Concrete Pavements	Smith, D.		●	●			⦿					●		
	Design: Ponds, Wetlands, and Modified Detention Basins														
1.8.1	Wetlands for Stormwater Treatment	Bautista, F & Geiger, N		●											
1.8.2	Constructed Wetlands Enhance SW Quality in Arizona	Fox P. & Wass, R.	⦿	●	●										
1.8.3	Wetland Vegetation	Guntenspergen, G. et al.		●									●		
1.8.4	Wet Pond as a Stormwater Runoff BMP: Case Study	Taylor, S & Currier, B		●	●			⦿	●				●		
	Design: Rainwater Harvesting														
1.9.1	Cisterns and Rainwater Harvesting Systems	Advanced Buildings		●					⦿						●
1.9.2	Sourcing Water from the Sky	Beers, S. K.		●					●						
1.9.3	Rainwater Catchment Systems For Domestic Supply	Gould, J. & Nissen E.	⦿	●	●		●	●	●	●	●				●
1.9.4	Recycling Urban Stormwater: Re-Establishing the Urban Ecosystem	Harper, C. & Lanier, L.		●					●						●
1.9.5	Water Harvesting and LID	Jones, D.; Humphrey, C. & Hunt, W.		●					●						●
1.9.6	Capturing Rainwater to Replace Irrigation Water for Landscapes: Rain Harvesting and Rain Gardens	Seymour, R. M.		●					●					⦿	●
1.9.7	On-Site Runoff Mitigation with Rooftop Rainwater Collection and Use	Stuart, D.		●		●			⦿						●
1.9.8	Practice Note 4: Rainwater Tanks	Water Sensitive Urban Design in Sydney		●				⦿	●		⦿		⦿		
	Design: Site Planning														
1.10.1	Practical Tips for Construction Site Phasing	Clayton, R.		●		⦿									
1.10.2	Practice Note 2: Site Planning	Coombes, P.		●										●	
1.10.3	Site Planning for Urban Stream Protection	Schueler, T.		●										●	

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	Design: Swales														
1.11.1	Characterization of Performance Predictors and Evaluation of Mowing Practices in Biofiltration Swales	Colwell, S.; Horner, R.; & Booth, D.		●											
1.11.2	Sediment Transport in Grass Swales	Nara, Y. & Pitt, R.		●									●		
	Design: Vegetated Filter Strips, Vegetated Slopes, and Riparian Buffers														
1.12.1	Roadside Vegetated Treatment Sites - Final Report	Caltrans	●	●	●								●		
1.12.2	Long-Term Effectiveness and Maintenance of Vegetative Filter Strips	Dillaha, T.; Sherrad, J. & Lee, D		●	●				●				◉	◉	
1.12.3	Vegetated Filter Strips: Application, Installation, and Maintenance	Leeds, R.; Brown, L.; Sucl, M. & Van Lieshout, L.		●	●										
	Monitoring Methods														
2.1	A Characterization of Water Quality in the Los Angeles River	Ackerman, Drew et al.	●		●								●		
2.2	Hydrologic Performance and Cost Analysis of an LID Stormwater Management System	Bachmann, N.; Brophy-Price, J.; Yuan, C.;			●			◉	●					●	
2.3	Assessment of Best Management Practice Effectiveness – Final Report	Brown, Jeffrey & Bay Steven	●	●	●				●			◉			
2.4	Comprehensive Protocols Guidance Manual (Stormwater Monitoring)	Caltrans	●		●										
2.5	Discharge Characterization Report	Caltrans	●		●								●		
2.6	SWAMP Quality Assurance & Quality Control	CSWRCB	●		●								●		
2.7	Construction Site Storm Water Sampling California's New Construction Sampling and Analysis Requirements	Forrest, C. and S. Mathews	●		●						●				
2.8	WSU Puget Sound Low Impact Development Pilot Project Monitoring	Hinman, C			●				●		◉			◉	
2.9	Linkages Between Watershed and Stream Ecosystem Conditions in Three Regions of the United States	Horner, R.; May, C. & Livingston, E			●				●				●	◉	
2.10	Automated Verification and Validation of Caltrans Stormwater Analytical Results	Kayhanian, M. et al.	●		●										

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2.11	The Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations	Kayhanian, M et al.			●								●		
2.12	Impact of Non-detects in Water Quality Data on Estimation of Constituent Mass Loading	Kayhanian, M. et al.	●		●										
2.13	Lessons Learned from In-field Evaluations of Phase I Municipal Storm Water Programs	Kosco, J. et al.	●		●						●		⦿	⦿	
2.14	Issues in Developing a Nonpoint Source Water Quality Monitoring Program for Evaluation of the Water Quality	Lee, G.F. and A. Jones-Lee	●		●								●		
2.15	Estimating Pollutant Mass Accumulation on Highways during Dry Periods	Lee-Hung, Kim	●		●								●		
2.16	Assessment of Efficient Sampling Designs for Urban Stormwater Monitoring	Leecaster, MK et al.	●		●				●				●		
2.17	Chapter 5: Effective Use of BMPs in Stormwater Management	Muthukrishnan, S. et al.	●		●				●				●		
2.18	Future Monitoring Strategies with Lessons Learned on Collecting Representative Samples	Othmer, E.F. and B.J. Berger	●		●										
2.19	Stormwater Runoff Water Quality Characteristics from Highways in Lake Tahoe, California	Regenmorter, L.C. et al.	●		●										
2.20	Review of Existing Stormwater Monitoring Programs Estimating Bight-wide Mass Emissions from Urban Runoff	Schiff, Kenneth	●		●								●		
2.21	Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits	Shumway, R.H. et al.			●								●		
2.22	Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern CA	Stormwater Monitoring Technical Committee	●		●		●						⦿	⦿	
		Modeling and Sizing Tools													
3.1	Modeling Stormwater Mass Emissions to the Southern California Bight	Ackerman, D & Schiff, K	●			●			●				●	●	
3.2	Contra Costa County Clean Water Program Hydrograph Modification Program HSPF Modeling Guidance	Anderson, S & Dubin, T.	●			●								●	

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3.3	Hydrograph Modification Management Using Simplified Low Impact Development Design	Beeman, C. & Cloak, D.	●	⦿		●									
3.4	Memorandum: Comparison of Contra Costa IMP and BAHM/WWHM3/HSPF	Beyerlein, D.	⦿			●					⦿		⦿	⦿	
3.5	The Bay Area Hydrology Model – A Tool for Analyzing Hydromodification Effects of Development Projects and Sizing Solutions	Bicknell, J.; Beyerlein, D. & Feng, A	●			●							⦿	⦿	
3.6	Modeling the Atmospheric Deposition and Stormwater Washoff of Nitrogen Compounds	Burian, S. et al.	●			●							●		
3.7	Modeling the Effects of Air Quality Policy Changes on Water Quality in Urban Areas	Burian, S. et al.	●			●						⦿	●		
3.8	BMP Decision Support System for Evaluating Watershed-Based Stormwater Management Practices	Cheng, M. S.; Akinbobola, C. & Zhang, Y.				●		⦿	●				●	●	
3.9	Aliso Creek Inn & Golf Course Redevelopment Project: Water Quality Technical Report	Geosyntec Consultants	●	●		●			●			⦿	●	●	⦿
3.10	Identification of Land Use with Water Quality Data in Stormwater using a Neural Network	Ha, H. & Stenstrom, M.				●							●		
3.11	Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices for the San Diego Region	Horner, R.	●			●								●	
3.12	Evaluating a Spreadsheet Model to Predict Green Roof Stormwater Management	Jarrett, A.; Hunt, W. & Berghage, R.		⦿		●									
3.13	Applications of the Site Evaluation Tool, a Site Scale Development Impacts Model	Job, S.				●			●				⦿	⦿	
3.14	Stormwater Management Model Analysis Report: Metro West	Low Impact Development Center				●			●					●	
3.15	Trace Metal Pollutant Load in Urban Runoff from a Southern California Watershed	McPherson, T.	●			●			●				●		
3.16	A New Classification System for Urban Stormwater Pollutant Loading: A Case Study in the Santa Monica Bay Area	Park, M. & Stenstrom, M.	●			●							●		

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3.17	Green Visions Plan for 21st Century Southern California: 12. Neighborhood Stormwater Quality Modeling	Sayre, J.; Devinny, J.; Wilson, J. & Yan X.	●			●	⦿								
3.18	Pelican Hills Resort – A Low Impact Approach in Southern California	Strecker, E. & Hesse, T.	●			●			●			⦿			
3.19	BMP Modeling Concepts and Simulation	US EPA				●									
3.20	Source Loading and Management Model: Urban Area Nonpoint Source Water Quality Model	USGS				●									
3.21	LATIS: A Spatial Decision Support to Assess Low Impact Site Development Strategies	Wilkerson, G. et al.				●			●						
	Planning & Smart Growth														
4.1	Double Standards, Single Goal: Private Communities and Design Innovation	Ben-Joseph, E.		⦿			●				⦿				
4.2	The Green Visions Plan for 21st Century Southern California: 10. Stormwater Quality Control Through Retrofit of Industrial Surfaces	Bina, Arash & Devinny, Joseph	●				●	⦿	●		⦿		⦿		
4.3	Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows	Kloss, C. & Calarusse, C.					●		●		●	●			
4.4	The Planning and Construction of an Urban Stormwater Management Scheme	Lloyd, S.; Wong, T. & Porter, B.		●			●								
4.5	The Stranger Amongst Us: Urban Runoff, The Forgotten Local Water Resource	Shapiro, N	●				●		●	⦿	●	⦿			⦿
4.6	Sustainability in Urban Storm Drainage: Planning Examples	Stahre, P.		●			●		●						
4.7	Sustainable Cities: Using LID Principles for Sustainable Hydrology on Urban Sites	Wildman, N.					●		●						
	Economic														
5.1	Downstream Economic Benefits of Conservation Development	Braden, J.; Johnston, D. & Price, T.				⦿	⦿	●	●					●	
5.2	The Economics of Stormwater BMPs in the Mid-Atlantic Region	Brown, W. & Schueler, T.						●					⦿	⦿	
5.3	An Economic Analysis of Green Roof Systems	Carter, T.						●							

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5.4	Changing Cost Perceptions: An Analysis of Conservation Development	Conservation Research Institute				◉	◉	●	●					●	
5.5	Tank Paddock: A Comparison Between Traditional and Water Sensitive Urban Design Approaches	Coombes, P. & Kuczera, G.		◉				●	●					●	
5.6	Costs and Infiltration Benefits of the Watershed Augmentation Study Sites	Dewoody, A.; Cutter, W. & Crohn, D.	●			●		●	●						
5.7	Best Development Practices: Doing the Right Thing and Making Money at the Same Time	Ewing, R.; Heflin, C.; DeAnna, M.; Porter, D.		●			●	●							
5.8	Cost of Urban Stormwater Control	Fan, C.; Field, R. et al.						●							
5.9	Dollars & Sense: Cut Development Costs and Generate Higher Lot Premiums with Conservation Design	Farnsworth, C.						●	●						
5.10	Cost Estimating Guidelines: Best Management Practices and Engineered Controls	Ferguson, T.; Gignac, R.; Stoffan, M.; Ibrahim, A & Aldrich, J		●				●							
5.11	LID on the SC Coastal Plain: Benefits, Costs, and Constraints	Fisher, H.; Burkhart, B. & Brebner, A.						●	●						
5.12	Exploring the Ecology of Organic Greenroof Architecture: Economic Advantages	Greenroofs.com						●							
5.13	Willingness to Pay for Low Impact Development Environmental Benefits	Hitzhusen, F.; Haab, T.; Sohngen, B.; Kruse, S. & Abdul-Mohsen, A.						●	●						
5.14	Water Facility Keeps Beaches Clean	Howard, R & Strawn,N	●					●	●						
5.15	A Cost Comparison of Conventional and Water Quality-Based Stormwater Designs	Liptan, T. & Brown, C.						●	●						
5.16	Quantifying Environmental Benefits, Economic Outcome and Community Support for Water Sensitive Urban Design	Lloyd, S.		●				●	●						
5.17	Using Benefit Cost Analysis to Assess LID	MacMullan, E.						●							
5.18	A Study of Nationwide Costs to Implement Municipal Stormwater Best Management Practices	Montgomery, J.						●							
5.19	Cost Analysis Methodology for Advanced Treatment of Stormwater: The Los Angeles Case	Moore, J. et al.	●	◉				●	●					●	

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5.20	LID Strategies and Tools for Local Governments: Building a Business Case	Powell, L.; Rohr, E.; Canes, M. et al.						●			●				
5.21	An Economic Analysis of Vegetative Buffer Strip Implementation Case Study: Elkhorn Slough, Monterey Bay, CA	Rein, F.	●					●	●			◉			
5.22	Costs of Urban Nonpoint Source Water Pollution Control Measures	SE Wisconsin Regional Planning Commission						●							
5.23	Post-Project Monitoring of BMPs/SUDs to Determine Performance and Whole-Life Costs	Weinstein, N; Lampe, L. et al.		◉		●		●							
5.24	Comparative Nutrient Export and Economic Benefits of Conventional and Better Site Design Techniques	Zielinkski, J.; Caraco, D. & Claytor, R.						●					●		
Manuals of Practice															
6.1	Bay Area Stormwater Management Agencies Association Manuals	BASMAA	●	●			●		●				●	●	
6.2	Stormwater BMP Handbooks	CASQA	●	●	◉		●	◉	◉		●		●	●	
6.3	Stormwater Guidelines for Green, Dense Redevelopment	City of Emeryville	●	●			●				◉		◉	◉	◉
6.4	LID Technical Guidance Manual for Puget Sound	Hinman, Curtis		●		●	◉	◉	◉		◉		●	●	◉
6.5	Truckee Meadows, NV LID Handbook: Guidance on LID Practices for New Development and Redevelopment	Kennedy/Jenks Consultants		●											
6.6	Stormwater Management Manual, Portland, OR	Portland Bureau of Environmental Services		●			◉				●		◉	◉	◉
6.7	Guidance Manual for Onsite Stormwater Quality Control Measures	City and County of Sacramento	●	●							●				
6.8	City of Salinas Development Standards Plan Low Impact Development	City of Salinas	●	●											
6.9	Landscape Water Conservation Design Manual	San Diego County	●	●											●
Training and Outreach Materials															
7.1	LA Targets Polluters with Ad Campaign	Anonymous	●						●	●					

Ref#	Title	Source	California Related	Design / Maintenance	Monitoring / BMP Performance	Modeling	Planning/Smart Growth	Cost / Economics	Case Studies	Training/Outreach/ Stakeholder Efforts	Regulatory	Resource Protection	Water Quality	Hydromodification	Water Cycle
7.2	Waste not, Want Not: The Potential for Urban Water Conservation in California	Gleick, P. et al.	●							●					●
7.3	LID Training for Western Developers	LIDC		●						●					
7.4	Selling LID: Audiences, Messages, and Media	Mull, K.								●					
7.5	Promoting Low Impact Development in Your Community	New England Finance Center								●	●				
		Pilot Projects													
8.1	Taking Trash Out of Runoff	Anonymous	●						●			●	●		
8.2	Flood Control Project Results in Children's Park	Anonymous	●		●				●						
8.3	Saving Precious Drops: Project Shows How Homeowners Wastewater	Brennan, P.	●		●				●				●	●	●
8.4	Bringing Sustainability to Los Angeles	Feinbaum, R.	●				⦿		●	●				●	●
8.5	Fort Bragg LID Pilot Projects	Lantz, C. & Weinstein, N.		⦿					●						
8.6	The Trickle-Down Effect	Sicaras, V.		⦿	●				●					●	
		Institutional and Program Development (Corporate and Government)													
9.1	Implementation of a Local LID Program: Case Study, Stafford County Virginia	Hubble, S.							●	●	⦿				
9.2	LID Strategy for Green Cove Basin: A Case Study in Regulatory Protection of Aquatic Habitat in Urbanizing Watersheds	City of Olympia; Thurston County							●	●	●				
9.3	Street Alternatives: Seattle Public Utilities' Natural Drainage System Program	Tackett, T.		⦿			●		●	●					
		Stakeholder Effort													
10.1	Second Nature: Adapting LA's Landscape for Sustainable Living	Condon, P. & Moriaty, S.	●	●						●					●
10.2	Going Green: How to Incorporate Stakeholders' Values for Sustainability	Kennedy, L. & Holmes, L.	●	●						●					
10.3	Understanding Potential Hurdles to Using Better Site	SCVURPPP & SCBWMI		●						●					
10.4	An Integrated Strategies for Managing Urban Runoff Pollution in Los Angeles County	Swamikannu, X.	●						●	●	●	●			

Ref#	Title	Source	California Related	Design / Maintenance	Monitoring / BMP Performance	Modeling	Planning/Smart Growth	Cost / Economics	Case Studies	Training/Outreach/ Stakeholder Efforts	Regulatory	Resource Protection	Water Quality	Hydromodification	Water Cycle
10.5	TreePeople-Los Angeles Area Non-Profit Org.	TreePeople	●							●					
Regulatory: Federal Level															
11.1.1	Clean Water Act	Federal Water Pollution Control Act									●				
Regulatory: State															
11.2.1	Statewide Stormwater Management Plan	Caltrans	●								●			●	
11.2.2	Draft General NPDES Permit for Construction Activities	Caltrans	●								●				
11.2.3	Draft NPDES General Permit #CAR000002, Waste Discharge Requirements for Discharges of Stormwater Runoff Associated with Construction Activity.	CA State Water Resources Control Board	●								●				
11.2.4	The Feasibility of Numeric Effluent Limits Applicable to Discharges of Stormwater Associated with Municipal, Industrial, and Construction Activity.	CA Stormwater Panel	●								●		●		
11.2.5	Water Conservation in Landscaping Act of 1990	State of California	●								●				●
11.2.6	Maryland Stormwater Management Act of 2007	State of Maryland									●				
11.2.7	Stormwater Management Rule	State of New Jersey									●				
11.2.8	Memo to RWQCB Executive Officers, State Water Board Order WQ 2000-11: SUSMP	Wilson, C.	●								●				
Regulatory: Regional and Local															
11.3.1	Anacostia Waterfront Corporation Environmental Standards	Anacostia Waterfront Corporation									●			●	
11.3.2	Growing Greener: Putting Conservation Into Local Codes	Arendt, R.					●				●				
11.3.3	The Role of Impervious Cover as a Watershed-based Zoning Tool to Protect Water Quality in the Christina River Basin of DE, PA, and MD.	Kauffman, G. & Brant, T.									●			●	
11.3.4	Standard Urban Stormwater Mitigation plan for Los Angeles County and Cities in Los Angeles County	Los Angeles Regional Water Quality Control Board	●								●				

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11.3.5	Conservation Design Resource Manual: Language and Guidelines for Updating Local Ordinances	Northeast Illinois Planning Commission & Chicago Wilderness					●	⦿			●				
11.3.6	Portland City Code Chapter 17.38 Policy Framework, Appeals, and Update Process	City of Portland									●				
11.3.7	Stormwater Standards: A Manual for Construction and Permanent Stormwater Best Management Practices Requirements	San Diego Municipal Code: Land Development Manual	●								●				
11.3.8	Waste Discharge Requirements for Discharges of Urban Runoff from the Municipal MS4s Draining the Watersheds of San Diego County, …	San Diego Regional Water Quality Board	●								●				
11.3.9	Hydromodification Management Plan – Final Report	SCVURPPP									●				
11.3.10	Seattle Green Factor	City of Seattle									●				●
11.3.11	Relating to Drainage Development Standards, Making Available for use of the "LID Technical Guidance Manual for Puget Sound"	Snohomish County Council									●				
11.3.12	Low-Impact Leader	Spinner, J.								⦿	●				
11.3.13	Watershed-Scale Planning for Aquatic Resources and Water Quality-Finding opportunities for Regulatory Coordination	Stein, E & Ebbin, M.									●	⦿			
11.3.14	Controlling Storm-Water Runoff with Tradable Allowances for Impervious Surfaces	Thurston, H. W.; Goddard, H. C.; Szlag, D.; Lemberg, B.		●			⦿	●	●		●				
11.3.15	Incentive-Based Land Use Policies and Water Quality in the Chesapeake Bay	Walls, M. & McConnell, V.									●	⦿	⦿	⦿	
11.3.16	Stormwater & LID Ordinance	Woodard & Curran									●				
11.3.17	Stormwater & LID Regulations	Woodard & Curran									●				
	Resource Protection														
12.1	Santa Monica Bay Restoration Project Report to the Legislature	State Water Resources Control Board									●	●			
12.2	Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program	Sate Water Resources Control Board									●	●			

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		Hydromodification													
13.1	Relationships between Impervious Surfaces within a Watershed & Measures of Reproduction in Fathead Minnows	Bannerman, R. & Weber, D.			●							●	⦿	●	
13.2	Urbanization Trhesholds, Stormwater Detention, and the Limits of Mitigation	Booth, D. & Jackson, C.			●							●		●	
13.3	Effects of Increased Urbanization from 1970's to 1990's on Storm Runoff Characteristics in Perris Valley, CA	Guay, J.	●											●	
13.4	Structural and non-Structural BMPs for Protecting Streams	Horner, R. & Rauscher, T.			●				●					●	
13.5	The Cumulative Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion	May, C.			●				●			●	●	●	
13.6	Effects of Regionwide Fires on Deposition, Runoff, and Emissions to the Southern California Bight	Maruya, K. & Stein, E.	●		●				●				●	●	
13.7	California Rivers and Streams: The Conflict Between Fluvial Process and Land Use	Mount, J.	●											●	
13.8	Using Stream Geomorphic Characteristics as a Long-Term Monitoring Tool to Assess Watershed Function	Ross Taylor and Associates			●				●					●	
13.9	Effect for Increases in Peak Flows and Imperviousness on Stream Morphology of Ephemeral Streams in Southern California	Stein, E.	●		●				●					●	
13.10	Managing Runoff to Protect Natural Streams: The Latest Developments on Investigation and Management of Hydromodification in CA	Stein, E. & Zaleski, S.	●											●	
13.11	The Effects of Watershed Urbanization on the Stream Hydrology and Riparian Vegetation of Los Penasquitos Creek, CA	White, M. & Greer, K.	●						●					●	
13.12	Effectiveness of Time of Concentration Elongation on Peak Flow Reduction	Zomorodi, K.												●	

Ref#	Title	Source	California Related	Design / Maintenance	Monitoring / BMP Performance	Modeling	Planning/Smart Growth	Cost / Economics	Case Studies	Training/Outreach/ Stakeholder Efforts	Regulatory	Resource Protection	Water Quality	Hydromodification	Water Cycle
	Ancillary Programs: Environmental														
	Ancillary Programs: Air														
14.1.1	Atmospheric Dry Deposition of Trace Metals in the Coastal Region of Los Angeles, CA	Sabin, L. et al.	●		●								●		
	Ancillary Programs: Water Supply														
14.2.1	Water at the Crossroads: The Intersection of Water Supply and Water Quality Issues and the Resulting Effect on Development	Beltran, S.; Singarella, P. & Katz, E.									●		⦿		●
14.2.2	Infiltration of urban Stormwater Runoff to Recharge Groundwater used for Drinking Water: A Study of the San Fernando Valley, CA.	Chralowicz, D.; Dominguez, A.; Goff, T. & Mascali, M et al.	●					⦿							●
14.2.3	A Grand Plan for Water Conservation	Grahl, C.		⦿			⦿								●
	Ancillary Programs: Thermal														
14.3.1	Stormwater Thermal Enrichment in Urban Watershed	Kieser, M. et al.		⦿	⦿				●				●		
	Ancillary Programs: Environmental Justice														
14.4.1	Testimony of Suzanne M. Michel, PhD. Water Resources Geography and Policy Environmental Policy Analyst, Institute for Regional Studies of the Californias, San Diego State University	Michel, S. M.	●								●	●	●		
14.4.2	Public Perceptions of Environmental Quality: A Survey Study of Beach Use and Perceptions in Los Angeles County	Pendleton, L. et al.	●							●		●			

Appendix A: Bibliography

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Appendix B: Annotated Bibliography by Critical Area

Annotated Bibliography by Critical Area

1. Procedures and Design

1.1. Design References for General LID and Multiple BMPs

1.1.1. Alameda Countywide Clean Water Program. 2005, Aug. **Protecting Water Quality in Development Projects: A Guidebook of Post-Construction BMP Examples**.

Brief Summary: Based on the SCVURPPP Guidebook of Site Design Examples, the photographically illustrated guidebook presents LID concepts, design techniques, and options through many built examples in Alameda County. The examples include residential, commercial, and public sites. A list of stormwater benefits for each practice at each site is included but not quantified. A matrix of site design BMPs and their locations is also included.

1.1.2. Bay Area Stormwater Management Association. 1999. **Start at the Source: Design Guidance Manual for Stormwater Quality Protection** http://www.basmaa.org/resources/files/Start%20at%20the%20Source%20%2D%20Design%20Guidance%20Manual%20for%20Stormwater%20Quality%20Protection%2Epdf

Brief Summary: The manual begins with an overview of stormwater issues, regulatory context, and the benefits of a low impact development approach. Then the manual provides specific guidance on the planning and design process, construction strategies, and suggestions on effective maintenance and operation. Chapters on site design details and case studies describe the various options for applying LID in the wide range of Bay Area development sites.

1.1.3. Bitting, Jennifer. 2006, August**. A Methodology and Evaluation Tool for Comparing Post-Construction Stormwater Best Management Practices.**
http://www.waterboards.ca.gov/centralcoast/stormwater/special_projects/spec_proj_index.htm

Brief Summary: The Dissertation describes a BMP decision tool. This tool describes a BMP selection tool which evaluates BMPs along four parameters: technical, environmental, social and economic. First, an overview of the stormwater issues that confront municipalities was provided and the available BMPs chronicled. The study outlines the decision making process, identifying components within the process to establish the need for the BMP selection tool. Then, two case studies which apply the tool were presented. First “hard gates’ are applied (i.e. absolute standards which eliminate BMPs from consideration) and then “soft gates” (ie choices through preferences) are used on the available BMPs to end with a final set of BMPs for a project. The tool is intended to provide both technical performance criteria and access to the various parties with vested interest in BMP selection by providing a means to evaluate environmental protection, economic development and social development of BMPs selected.

1.1.4. California Stormwater Quality Association (CASQA). January 2003. **California Stormwater BMP Handbook: New Development and Redevelopment**. http://www.cabmphandbooks.com/

Brief Summary: One of four BMP handbooks geared toward different audiences. The others are Construction, Commercial and Industrial, and Municipal. The manuals include a summary of regulatory requirements, planning process (sited design, source controls, and treatment controls), and BMP fact sheets for source control and treatment controls.

1.1.5. California Stormwater Quality Association (CASQA). January 2003. **BMP Maintenance Fact Sheets**.
http://www.scvurppp-w2k.com/Treatment_Control_BMPs.htm

Brief Summary: Website contains 22 inspection and maintenance fact sheets for BMPs listed in the California Stormwater BMP Handbook.

1.1.6. California Department of Transportation (Caltrans). April 2006. Caltrans **Treatment BMP Technology Report**. CTSW-RT-06-167.02.02.
http://www.dot.ca.gov/hq/env/stormwater/annual_report/2006/Attachments/CTSW-RT-06-167.02.02.pdf

Brief Summary:

1.1. Report is a collection of fact sheets on untested and unapproved BMPs (App. B), promising and currently studied BMPs (App. C), and successfully piloted and approved BMPs (App. D).
1.2. Caltran Stormwater BMP Pilot Projects (April 2006) (from Table 2-1)

Table 2.1(CTSW-RT-06-167.02.02)

BMP Type	# of Projects	Study Status	Approved for Caltran Facilities
Alternative Media Filters	1	Monitoring Ongoing	
Austin Filter with Alt Media	2	Monitoring Ongoing	
Austin Sand Filters	8	Varies	X
Biofiltration Strips	3	Study Complete	X
Biofiltration Strips: Roadside Vegetated Treatment Sites	8	Monitoring Ongoing	
Biofiltration Swales	6	Study complete	X
Bioretention	3	Under Design or Construction	
Compost StormFilter	3	Monitoring Ongoing	
Constructed Wetland	1	Project Cancelled	
Continuous Deflection Separators	4	Monitoring Ongoing	
Delaware Sand Filters	1	Monitoring Ongoing	X
Detention Basins	23	Monitoring Ongoing	X
Drain Inlet Insert	6	Monitoring Ongoing	
Gross Solids Removal Devices	21	Varies	Varies

Infiltration Basins	2	Study Complete	X
Infiltration Trench	2	Study Complete	X
Multi-Chamber Treatment Train	3	Study Complete	X
Oil/Water Separator	1	Study Complete	
Sand Filters	1	Study Complete	
Sand Traps	6	Monitoring Ongoing	X
Storm Filter (Perlite/Zeolite)	1	Study Complete	
Wet Basin	1	Study Complete	X

1.1.7. California Department of Transportation (Caltrans). January 2004. BMP **Retrofit Pilot Program**. CTSW-RT-01-050. http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/_pdfs/new_technology/CTSW-RT-01-050.pdf.

Brief Summary: The results of the study, which was the first significant evaluation of BMP retrofits in a climate of southern California's type, were consistent with the performance of BMPs in previous studies. Study included Austin sand filters (5), Delaware sand filter (1), MCTT (2), Storm-Filter (1), Drain inlet Inserts (6), Biofiltration Swale (6), Biofiltration Strip (3), Infiltration Basin (2), Infiltration Trench (2), Wet Basin (1), Oil-Water Separator (1), and CDS (1). Infiltration was one of the most significant factors in reducing runoff pollutant loads. The impact on groundwater quality was not successfully investigated. An unexpected problem was vector breeding in BMPs with over 72 hours of standing water.

1.1.8. California Department of Transportation (Caltrans). April 2006. **Stormwater Monitoring and BMP Development Status Report**. CTSW-RT06-167.02.01. http://www.dot.ca.gov/hq/env/stormwater/annual_report/2006/Attachments/CTSW-RT-06-167.02.01.pdf

Brief Summary: Report describes current and ongoing Caltrans BMP pilot studies and provides a literature review of previous studies pertaining to stormwater treatment technology. This report summarizes information on stormwater treatment technology, erosion control, and stormwater quality studies in California.

1.1.9. Caraco, D. and T. Schueler. 1999. **Stormwater Strategies for Arid and Semi-Arid Watersheds**. Water Science and Technology. 28(3-5): 241-259.

Brief Summary: Article reviews strategies for managing stormwater in regions of scarce water based on an extensive survey of 30 stormwater managers from arid and semi-arid regions.

- Small rainfall depths – Los Angeles, CA (annual rainfall – 12"; days of rain per year – 22; 90% rainfall event – 1.3"; annual evaporation rate – 60; 2yr-24hr – 2.5"; 10yr-24hr – 4.0")
- Pollutant loads in stormwater are often greater, especially bacteria
- Vegetation Cover is sparse
- Sediment movement is greater: "For example, Trimble (1997) found that stream channel erosion supplied more than two thirds of the annual sediment yield of an urban San Diego Creek."

- Dry Weather Flows are rare, unless Supplemented by Return Water.
- Article emphasizes source control: pollution prevention, street sweeping and storm drain inlet clean-outs.
- Better site design: California development style is overly impervious.
- Contains helpful table. “Design Modifications for Stormwater Practices in Arid and Semi-Arid Watersheds

1.1.10. Claytor, Jr., Richard A. 2003 **Critical components for Successful Planning, Design, Construction and Maintenance of Stormwater Best Management Practices**. National Conference on Urban Storm Water: Enhancing Programs at the local level. Proceedings. EPA/625/C-03/003. http://www.epa.gov/owow/nps/natlstormwater03/27Claytor.pdf

Brief Summary: (abstract from document) *This paper presents a common nomenclature for structural stormwater best management practices (BMPs) and reviews the several critical elements that must be addressed to ensure that BMPs meet watershed protection goals. A set of key planning, design and implementation elements is reviewed. The paper documents some of the many possible pitfalls that planners, designers, and local officials are faced with during the BMP implementation process. Several real world examples of successful and failed BMP implementation are cited as illustrations. The old adage, "the devil is in the details," is illustrated to alert stormwater management practitioners to critical components throughout the BMP implementation process.*

1.1.11. Coffman, Larry S. 2000. **Low-Impact Development Design: A New Paradigm for Stormwater Management Mimicking and Restoring the Natural Hydrologic Regime: An Alternative Stormwater Management Technology**. National Conference on Tools for Urban Water Resources Management & Protection. Proceedings. EPA/625/C-00/001. http://www.epa.gov/ORD/WebPubs/nctuw/Coffman.pdf

Brief Summary: The paper gives an introduction to LID and explains the steps of LID design The paper defines the development of the LID concept and details the LID approach to site planning. As defined here, LID seeks to create an environmentally functional landscape that mimics natural watershed hydrologic function in a predeveloped state Eight site planning steps are outlined and discussion of the LID hydrologic response analysis process is presented. Fourteen LID BMPs are evaluated for applicability to five typical stormwater issues. A short description of roadblocks to LID and ways to address those roadblocks is provided.

1.1.12. Coffman, L. S., Clar, M. L., & Weinstein, N. (1998). **New Low Impact Design: Site Planning and Design Techniques for Stormwater Management in Revolutionary Ideas in Planning: Proceedings of the 1998 National Planning Conference**. AICP Press. http://design.asu.edu/apa/proceedings98/Coffmn/coffmn.html

Brief Summary: This paper presents LID as a cost effective alternative stormwater management tool and as a natural resource protection strategy. Discussion focuses on how developers can save money by disturbing less ground, preserving and working with existing natural systems and achieve mandated stormwater controls. Further discussion centers on the role of education and increased public awareness that stormwater management can provide multiple benefits including environmental stewardship.

1.1.13. Cohen, A. B. 2004. Narrow Streets Database. http://www.sonic.net/abcaia/narrow.htm

Brief Summary: This databases from 1997 is a product of the Transportation Task for the Congress for the New Urbanism. In addition to a survey of communities with narrow street standards, a list of publications relating to narrow streets can be found.

1.1.14. Corish, K. 1995. **Clearing and Grading: Strategies for Urban Watersheds**. Environmental Land Planning Series. Metro. Wash. Coun. Gov. Washington, DC 48 pp.

Brief Summary: Publication offers recommendations for minimizing the sediment and hydromodification impacts of clearing and grading on streams.

1.1.15. Eason, C., Pandey, S., Feeney, C., van Roon, M., & Dixon, J. (n.d.). **Low Impact Urban Design and Development: Making It Mainstream**. http://nzsses.auckland.ac.nz/conference/2004/Session5/14%20Eason.pdf

Brief Summary: (abstract from document) *This paper reviews the literature on low impact urban design and development and presents preliminary data on the utility of treatment walls and reengineered soils to contain water, contaminants, and sediment. Evidence is also presented from stakeholder interviews to identify impediments to the implementation of these approaches.*

1.1.16. Ferguson, Bruce K. 1994. **Stormwater Infiltration**. Boca Raton: CRC Press.

Brief Summary: The book advocates for infiltration as the best approach to stormwater management. It includes information about soils, vegetation infiltration, hydrology, design criteria, site layout, construction process for surface and subsurface basins, porous paving materials, feasibility, maintenance, and performance. Construction graphics, hydrology calculations, and case studies are also presented.

1.1.17. Friends of the San Francisco Estuary. 2005, Nov. **Protecting Water Quality in the Northern San Francisco Bay Area: A Guidebook of Post-Construction Stormwater Best management Practices in Action**.

Brief Summary: Based on the SCVURPPP Guidebook of Site Design Examples, the photographically illustrated guidebook presents LID concepts, design techniques, and options through many built examples in the Northern San Francisco Bay Area. The examples include residential, commercial, and public sites. A list of stormwater benefits for each practice at each site is included but not quantified.

1.1.18. Guillette, Anne. 2007. **Achieving Sustainable Site Design through Low Impact Development Practices**. Whole Building Design Guide. http://www.wbdg.org/design/lidsitedesign.php

Brief Summary: The website provides an introduction to LID as a sustainable design approach, LID design steps, and links to LID resources. Graphic representations of LID concepts, processes supplement the text. Application cases for Olympia, Washington, Portland, Oregon, Santa Monica, California, King County Washington, and Maplewood Minnesota area summarized. The links range from publication and design/analysis tools to identifying organizations that promote or use LID, LEED®.

1.1.19. Hager, M.C. 2003. **Low-Impact Development: Lot-level Approaches to Stormwater Management are Gaining Ground**. *Stormwater*. www.lowimpactdevelopment.org/lid%20articles/stormwater_feb2003.pdf

Brief Summary: The article gives an introduction to the disciplines which influenced the development of LID and explains the steps of LID design. A cost comparison of LID and conventional stormwater management and prognosis for future costs is discussed.

1.1.20. Kane, B. P. 2005. **Let That Soak In: Breaking Ground with Low Impact Development Methods**. *Landscape Architecture*. pp 70-81.

Brief Summary: This study contains general design information on LID for a Conservation Development in an Illinois suburb on Chicago.

1.1.21. Lemus, Judith D. et al. 2003. **Stormwater Mitigation for Architects and Developers**. University of Southern California Sea Grant Program. http://www.usc.edu/org/seagrant/Publications/StormWaterRpt.pdf

Brief Summary: Paper provides an overview of low impact development and considerations for the southern California climate. In semi-arid southern California, 90% of the rain events in a given year are less than 0.8 inches. California's wet season occurs in the winter when plant growth is decreased. This may limit the dissolved pollutant removal capabilities of vegetative BMPs like bioretention and wet ponds. Wet ponds in arid regions require some supplemental source of water to counter evaporation during dry periods. Biofilter size: minimum length for strips is 10ft, and for swales an area of 1000-1200 sq. ft. per acre of impervious is recommended. Case Study: Village Homes in Davis, CA utilizes common drainage areas, vegetated swales, and percolation beds that infiltrate rainfall. Report includes figures appropriate to CA.

1.1.22. Liptan, Thomas & Murase, Robert K. 2002. **Watergardens as Stormwater Infrastructure in Portland Oregon**. Lewis Publishers.

Brief Summary: The document examines the application of vegetated BMPs, green infrastructure in Portland, OR. The document gives design and performance information for a few case studies.

1.1.23. Low Impact Development Center. 2005, November. **Low Impact Development for Big Box Retailers**. EPA Assistance Agreement # AW-83203101. http://lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf

Brief Summary: The document describes LID strategies and techniques for big box commercial developments. Case studies and fact sheets on ten LID technologies are presented.

1.1.24. Low Impact Development Center, Inc. (n.d.). **Introduction to Low Impact Development**. http://www.lid-stormwater.net/intro/background.htm

Brief Summary: The website provides an overview of to LID. Website Includes a link to LID design tools and construction details for LID techniques as applied in a variety of settings.

1.1.25. Metzger, Marco E. 2004. **Managing Mosquitoes in Stormwater Treatment Devices.** California Department of Health Services, Vector-Borne Disease Section. University of California, Division of Agriculture and Natural Resources http://www.ucmrp.ucdavis.edu/publications/managingmosquitoesstormwater8125.pdf

Brief Summary: This document addresses mosquito management in LID sites. Mosquito life cycle, factors that might effect mosquito development in treatment BMPs and guidelines for Mosquito management are the focus of this publication.

1.1.26. Natural Resource Defense Council. (n.d.). **Chapter 12: Low Impact Development**. *Stormwater Strategies: Community Responses to Runoff Pollution*. http://www.nrdc.org/water/pollution/storm/chap12.asp

Brief Summary: The chapter provides an introduction to LID summarizes ten common LID practices, lists benefits and provides many case studies from around the country. The physical, chemical and biological processes that are at work in LID facilities are identified and a discussion of LID retrofits for the Urban Environment is included as are seven specific benefits of LID applications.

1.1.27. Potts, A.; Adams, M. & Cahill, T. 2007, March 12-14. **A High-Density, Low Impact Development with Infiltration in a Limestone Area: The Village at Springbrook Farms.** 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation chronicles a LID high density residential site with high infiltration. Emphasis is placed on design effectiveness and appropriate separation of LID BMP and the local water table.

1.1.28. Rushton, B. 1999. **Low Impact Parking Lot Design Reduces Runoff and Pollutant Loads: Annual Report #1**. Southwest Florida Watershed Management District, Brooksville, FL.

Brief Summary: The Florida Aquarium parking lot in Tampa, FL was used to test various LID designs. The demonstration compared three paving surfaces and basins with and without swales. The preliminary results from the first year of a two year study showed a 30% reduction in runoff volume by the swales and 10-15% reduction in runoff volume by the pervious pavement.

1.1.29. San Mateo Countywide Stormwater Pollution Prevention Program. 2004. **Developments Protecting Water Quality: A Guidebook of Site Design Examples.**
http://www.flowstobay.org/pdfs/bmp/Construction%20Series/SiteDesignGuidebook.pdf

Brief Summary: Based on the SCVURPPP Guidebook of Site Design Examples, the photographically illustrated guidebook presents LID concepts, design techniques, and options through many built examples in San Mateo County. The examples include residential, commercial, and public sites. A list of stormwater benefits for each practice at each site is included but not quantified. A matrix of site design BMPs and their locations is also included.

1.1.30. Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). 2007, Feb. **Developments Protecting Water Quality: A Guidebook of Site Design Examples**.

Brief Summary: The photographically illustrated guidebook presents LID concepts, design techniques, and options through many built examples in Santa Clara Valley. The examples include residential, commercial, and public sites. A list of stormwater benefits for each practice at each site is included but not quantified. A matrix of site design BMPs and their locations is also included.

1.1.31. Sayre, J. M.; Devinny, J. S. & J. P. Wilson. 2006. **Green Visions Plan for 21st Century Southern California: 11. Best Management Practices (BMPs) for the Treatment of Stormwater Runoff.** University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California.

Brief Summary: This segment of the Green Visions Plan for the Santa Monica Mountains Conservancy and Mountains Recreation and Conservation Authority gives an introduction to BMPs appropriate to the Los Angeles area. A list of BMP modifications appropriate to arid and

semi-arid watersheds is provided. There are also several case studies of BMPs implemented and planned for the San Fernando Valley.

1.1.32. Schueler, Thomas. 1995. **Site Planning for Urban Stream Protection**. Metropolitan Washington Council of Governments: Washington D.C. http://www.cwp.org/SPSP/TOC.htm

Brief Summary: The guidebook emphasizes the impacts of impervious surfaces. The guide gives site planning information for protecting water resources and minimizing impervious surfaces. There is also design and performance data for BMPs.

1.1.33. Stormwater Manager's Resource Center. 2002. **Better Site Design Fact Sheets: Green Parking, Alternative Pavers, Alternative Turnarounds, Narrow Residential Streets, and Open Space Design**. Center for Watershed Protection. www.stormwatercenter.net.

Brief Summary: The Center for Watershed Protection has produced fact sheets for five site design BMPs, which detail how the practices can reduce pollutant loads in stormwater and how to incorporate these practices into site design.

1.1.34. Stormwater Manager's Resource Center. 2002. **Stormwater Management Fact Sheets: Porous Pavement, Infiltration Basin, Bioretention, Infiltration Trench, Grassed Filter Strip, Wet Pond, Dry Extended Detention Pond, and On-Lot Treatment**. Center for Watershed Protection. www.stormwatercenter.net

Brief Summary: The Center for Watershed Protection has produced fact sheets for stormwater management BMPs. Each fact sheets provides quick summaries of practices, including costs at the planning level.

1.1.35. Urbonas, B.R., & Stahre, P. 1993. **Stormwater: Best Management Practices including Detention**, Englewood Cliffs: Prentice Hall

Brief Summary:

1.1.36. US EPA. 1999. **BMP Fact Sheets** 832-F99-0XX. http://www.epa.gov/owm/mtb/mtbfact.htm

Brief Summary: US EPA has many BMP fact sheets on its Municipal Technologies website .Fact sheets describe the practices, applicability and design criteria for each. Sizing, technical data on effectiveness of the practice, operations and maintenance as well as cost information is also summarized. Each fact sheet has a list of references for further information.

1.1.37. Woods-Ballard, Bridget et. al. 2005. **Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems**. Water Environment Research Foundation (WERF). Stock No. 01CTS21TA.

Brief Summary: Report identifies research gaps for 11 types of BMPs based on a review of literature on research and studies done in the past 25 years.

1.1.38. Woodward-Clyde Consultants. 1996, June 11. **Parking Lot BMP Manual.** Santa Clara Valley Nonpoint Source Pollution Control Program.

Brief Summary: The document provides information on BMPs appropriate for parking lots.

1.1.39. Yingxia, Li. 2005. **Particle Size Distribution in Highway Runoff**. Journal of Environmental Engineering. Sep 2005, Vol. 131, Issue 9, p1267-1276

Brief Summary: Particles in highway runoff contain various sorted pollutants, and many best management practices (BMPs) are selected for particle removal efficiency, which makes particle size distribution a crucial BMP design parameter. Particles between 2 and 1,000 μm in diameter were quantified for three rainfall events during the 2002-2003 rainy season at three highway sites in west Los Angeles. Rainfall, runoff flow rate, and a large suite of water quality parameters

1.2. Bioretention

1.2.1. Coffman, Larry S. & Winogradoff, Derek A. 1999. **Bioretention: An Efficient, Cost Effective Stormwater Management Practice**. National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments. Proceedings. USEPA Office of Research and Development. EPA/625/R-99-002. http://www.epa.gov/nrmrl/pubs/625r99002/625r99002.pdf

Brief Summary: This section of the conference proceedings provides design, construction, maintenance, and monitoring findings on bioretention projects in the late 1990s

1.2.2. Chavez, R. A.; Brown, G. O. & Storm, D. E. 2007, March 12-14. **Design and Construction of Bioretention Cells in Grove, Oklahoma**. 2^{nd} National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation described the design of nine cells by graduate students from Oklahoma State University. Fly ash was mixed into the cell media to absorb phosphorous.

1.2.3. Davis, A.; Shokouhian, M.; Sharma, H. & Minami, C. 1998. **Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics**. Report 01-04-31032. Final report to Prince George's County, Maryland.

Brief Summary: The report presents monitoring data on bioretention cell demonstration projects in Maryland.

1.2.4. Dietz, Michael E. & Clausen, John C. 2005. **A Field Evaluation of Rain Garden Flow and Pollutant Treatment**. *Water, Air, and Soil Pollution*. Vol. 167, pp. 123-138

Brief Summary: Rain gardens treating shingled roof runoff in Connecticut were tested for pollutant removal ability. Low treatment of nutrients was observed. Most samples had metal pollutant levels below detection limits.

1.2.5. Greer, Randell. 2007, March 12-14. **Developing a Standard & Specification for Bioretention Soil Media: A Delaware Perspective**. 2^{nd} National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: Many bioretention cells fail because of inappropriate soil media. The presentation provides a recommendation for equal parts by volume, triple-shredded hardwood mulch, sphagnum peat, and concrete sand.

1.2.6. Hunt, W.F. et. al. 2006. **Evaluation Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina**. Journal of Irrigation and Drainage Engineering. Nov/Dec 2006.

Brief Summary: Three bioretention field sites in North Carolina were studied for their pollutant removal ability. The high mass removal rates were due substantially to the reduction in outflow volume. The cell with the lower P-index soil media had higher Phosphorus removal the cells with the higher P-index.

1.2.7. Hunt, W.F. & Sharkey, L.J. 2005. **Design Implications on Bioretention Performance as a Stormwater BMP: Water Quality and Quantity**. Paper # 052201, 2005 ASAE Annual Meeting

Brief Summary: A paired study of bioretention cells in North Carolina investigated the effectiveness of an internal storage zone or anaerobic zone. The cells with the internal storage had significantly lower total Phosphorus concentrations, but not total Nitrogen.

1.2.8. Hsieh, Chi-Hsu & Davis, Allen. 2005. **Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff**. *Journal of Environmental Engineering*. Vol. 131, Iss. 11, pp. 1521-1531, Nov. 2005.

Brief Summary: The study investigated the pollutant removal capability of different bioretention media characteristics. (from abstract) *The objective of this study is to provide insight on media characteristics that control bioretention water management behavior. Eighteen bioretention columns and six existing bioretention facilities were evaluated employing synthetic runoff.*

1.2.9. Jones, P. S. & Davis, A. P. 2007, March 12-14. **Characterization of Metal Accumulation in Bioretention Media.** 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes the results from a study of metals accumulation in a bioretention cell treating runoff from a parking lot.

1.2.10. Kim, Hundo; Seagran, Eric & Davis, Allen. 2003. **Engineered Bioretention for Removal of Nitrate from Stormwater Runoff**. Water Environment Research.

Brief Summary: Conventional bioretention facilities have low to no nitrate attenuation. The study tested various media additives and an anoxic zone to produce conditions for microbial denitrification. Newspaper was demonstrated to be the best solid-phase electron-donor substrate for denitrification.

1.2.11. Lancaster, Alice. 2007, March 12-14. **Reducing Combined Sewer Overflows Using Cisterns and Rain Gardens**. Seattle Public Utilities RainCatchers. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation described a study of how rain gardens and cisterns would reduce CSO flow from a residential neighborhood of Seattle.

1.2.12. Lenhart, J. H. 2007, March 12-14. **Compost as a Soil Amendment for Water Quality Treatment Facilities**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes a study of three composts, mixed yard debris, steer manure, and leaf compost, as a soil amendment. The leaf compost had the least potential for leaching phosphorous and nitrogen.

1.2.13. Leuthold, Kurt; Rozumalski, Fred; and Yetka, Leslie. 2004. **Burnsville Stormwater Retrofit Study**. City of Burnsville and Barr Engineering. http://www.ci.burnsville.mn.us/DocumentView.asp?DID=449

Brief Summary: The Burnsville study presents a paired watershed approach for evaluating LID. 17 rain gardens were built as a retrofit to a 1980s residential neighborhood along a single residential street. An adjacent residential street without rain gardens was used as a control.

1.2.14. Thomas, A. M.; Christian, D.; Gamble, C. and Killips, J. 2007, March 12-14. **City of Lansing, Use of Bioretention in an Ultra-Urban Setting**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation described a Tetra Tech bioretention design project. The project proposes bioretention in the landscaping zones along a visible ultra-urban street of Lansing, MI.

1.3. Filters

1.3.1. Anonymous. 1997, September 1. **Low Tech Filtration System Uses Leaves to Remove Solids**. *Engineering News Record*. ENR, Iss. 239 p. 12.

Brief Summary: Article describes a stormwater management system that uses composted leaves as a filter medium. The filter removes 80% of all suspended solids, metals, phosphorus, hydrocarbons and other pollutants.

1.3.2. Claytor, R. A. and Schueler T. R. 1996. **Design of Stormwater Filtering Systems**. Center for Watershed Protection, Silver Spring, MD.

Brief Summary: The document presents design information for stormwater filtering systems.

1.3.3. Hipp, J. Aaron; Ogunseitan, Oladele; Lejano, Raul & Smith, Scott. 2006. **Optimization of Stormwater Filtration at the Urban/Watershed Interface**. Environmental Science & Technology 8/1/2006, Vol. 40, Issue 15, p4794-4801.

Brief Summary: The research describes the testing of 10 filters for curb inlets. Based on varying pollutant loads and filter materials, the effectiveness for retaining pollutants ranged from 0 to 90%. The decision to employ a particular type of filter will depend on land use patterns and TMDL requirements. In a case study, the City of Costa Mesa in Orange County, a municipality with 498 curb inlets could meet TMDLs with a strategically place 158 filters.

1.3.4. Pitt, R. & Clark, S. 1999. **Stormwater Treatment at Critical Areas: Evaluation of Filtration Media**. EPA/600/R-00/010
http://www.epa.gov/ord/NRMRL/pubs/600r00010/600r00010chp4.pdf

Brief Summary: Eight filter fabrics and seven filter media types with sand were tested in a lab setting to evaluate their potential for removing typical stormwater pollutants. The study compared influent and effluent particle size distributions over the range of 4 to 128 μm for each fabric and media. The stormwater runoff source was Stafford Township, NJ.

1.3.5. Pradhan, A. U. (n.d.). **Field Evaluation of Low Impact Development Practices for Treatment of Highway Runoff in an Ultra Urban Area.** University of Maryland.
https://drum.umd.edu/dspace/bitstream/1903/3321/1/umi-umd-3161.pdf

Brief Summary: This study is organized as a performance comparison of BMPs for stormwater management. TSS, Metals and Nutrients were observed. The study makes the case that highway runoff is comparable to urban stormwater runoff with the implication that findings from one may be generalized to the other. Relative merits of LID BMPs are summarized (Mehler and Ostrowski, 1999) and selection of BMPs for testing yielded two “first flush” BMPs. Gutter filters and bioinlets were evaluated for the treatment of highway runoff quality in Mt. Rainier, MD. (metro DC).

1.4. Green Roofs

1.4.1. Breuning, Jörg (Spring 2007) **Fire & Wind on Extensive Green Roofs**. *Green Roof Infrastructure Monitor*. Vol. 9, No. 1, pg 12-13.

Brief Summary: The article describes German research on fire and wind issues with green roofs.

1.4.2. Fassman, E. A.; Simcock, R. & Mountfort, C. 2007, March 12-14. **Extensive Roof Design and Implementation in Auckland, New Zealand**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: Presentation describes information on a green roof pilot project in Auckland, New Zealand. Materials adaptation for what is locally available in New Zealand and its performance is presented. In this study, three substrate combinations were evaluated. Lab tests followed the German “FLL” standards. Evaluation of New Zealand native species for Green Roofs is ongoing.

1.4.3. Friedrich, C. 2007, March 12-14. **Selecting the Proper Components for a Green Roof Growing Media**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes appropriate green roof media and various examples of extensive and intensive green roofs. Depths of growing media for various plants is documented and the six properties essential for growing media outlined.

1.4.4. Green Roofs for Healthy Cities. 2006. **The Green Roof Infrastructure Monitor**. Volume 8, No.1. Spring 2006. http://www.greenroofs.com/grim.htm

Brief Summary: The publication provides green roof design information and case studies. Quarterly issues are available from the website.

1.4.5. Hilten, R. N. & Lawrence, T. M. 2007, March 12-14. **Using Green Roofs and Other BMPs to Reduce the Need for Stormwater Retention Capacity Requirements**. 2nd National Low Impact Development Center. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes a study of a green roof on the University of Georgia, Atlanta building. The green roof was modeled and compared the effectiveness and cost to other BMPs.

1.4.6. Kiers, Haven. 2002. **Green Roofs: The Last Urban Frontier**. Thesis, Master of Landscape Architecture. University of California, Berkeley.

Brief Summary: The thesis investigates the history, components, benefits, and challenges of building green roofs. The author intended it to be a comprehensive reference for contemporary green roof information.

1.4.7. Liptan, T. & Strecker, E. 2003, February. **EcoRoofs (Greenroofs) – A More Sustainable Infrastructure**. Conference on Urban Stormwater: Enhancing Programs at the Local Level.

Brief Summary: (from document abstract) *This paper will present the overall City* green roof *program, including a discussion of the incentives and assistance the City provides to encourage development projects to employ green roofs. The paper will review some of the installations that have occurred and discuss some of the practical lessons that have been learned regarding green roofs.*

1.4.8. Long, B.; Clark, S. E.; Baker, K. H. & Berghage, R. 2007, March 12-14. **Selecting a Green Roof Media to Minimize Pollutant Loadings in Roof Runoff.** 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The methodology is clearly explained in this study which examines the pollutant removal ability of several green roof media types and additives. Data is presented in tabular form and overall conclusions based on that data are presented.

1.4.9. Los Angeles, City of. 2006. **Green Roofs – Cooling Los Angeles, A Resource Guide, III-9**. Environmental Affairs Department http://www.fypower.org/pdf/LA_GreenRoofsResourceGuide.pdf

Brief Summary: The guide provides a background on green roofs in other parts of the country and a step by step process for planning, designing, constructing, and maintaining a green roof in Los Angeles. The sections on the permit process and climate appropriate plant list are particularly helpful.

1.4.10. Portland, City of. 2000. **Ecoroofs: Question & Answers**. City of Portland Bureau of Environmental Services. Updated Sept 2005. http://www.portlandonline.com/shared/cfm/image.cfm?id=153098

Brief Summary: The City of Portland brochure provides a list of benefits and design information including costs, construction details, applicability and operations and maintenance considerations for green roofs in a question and answer format. The brochure is illustrated with photographs of Portland green roof examples and concludes with a list of local permits and vendors.

1.4.11. Scholz-Barth, K. 2001, Jan/Feb. **Green Roofs, Stormwater Management from the Top Down**. *Environmental Design and Construction*.

Brief Summary: The article examines materials, maintenance needs, energy efficiency, limitations, and cost considerations for green roofs. Additional green roof resources are provided.

1.4.12. Sharp, Randy. 2007. **Green Walls 101: Introduction to Systems and Design**. *Green Roof Infrastructure Monitor.* Vol. 9, No. 1, pg 16-17. http://www.greenroofs.org/baltimore/index.php?page=courses

Brief Summary: Article presents components, functions, and benefits of green walls. Also being offered as a training course from Green Roofs for Healthy Cities, Inc (North America).

1.5. Infiltration Basins and Trenches

1.5.1. Building Research Establishment (BRE). 1991. **Digest 365 Soakaway Design**.

Brief Summary: This booklet provides design and construction procedures for infiltration devices and provides some examples.

1.5.2. Emerson, Clay & Traver, Robert. 2005, July/August. **Constructing an Infiltration Trench Retrofit BMP**. *Stormwater.* http://www.forester.net/sw_0507_constructing.html & Project Website:http://egrfaculty.villanova.edu/public/Civil_Environmental/WREE/VUSP_Web_Folder/IT_web_folder/IT_main.html

Brief Summary: The article and project website describe the design, construction, and performance of an infiltration trench on the Villanova campus. The trench was designed for both performance and aesthetic benefits.

1.6. Landscaping

1.6.1. Alsentzer, U. K. & Kenny, J. 2007, March 12-14. **The Benefits of Trees**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation gives quantitative and qualitative benefits of incorporating trees into development projects with particular focus on the health and economic value of trees in a community.

1.6.2. Caltrans. 2005, July. **Native Shrub Germination Relative to Compost Type, Application Method, and Layer Depth**. CTSW-RT-05-069.06.2

Brief Summary: The study tested soil stabilization specifications for the establishment of vegetation and the reduction of runoff and sediment transport.

1.6.3. Clean Water Newport. (n.d.). **Synthetic Turf Demonstration Sites**. http://www.cleanwaternewport.com/synturf.htm

Brief Summary: The website article shows how synthetic turf can look attractive, use no landscaping runoff, and allow stormwater to infiltrate.

1.6.4. Harris, Richard W. 1992. **Arboriculture: Integrated Management of Landscape Trees, Shrubs and Vines.** 2nd ed. Englewood Cliffs: Prentice Hall.

Brief Summary: The textbook provides information on the cultivation of trees shrubs and vines. This is a general overview of Arboriculture which addresses the field as a whole.

1.6.5. O'Brien, Bart; Landis, Betsy; & Mackey, Ellen. 2006. **Care & Maintenance of Southern California Native Plant Gardens**. Metropolitan Water District of Southern California. Download on California Native Plant Society: www.cnps.org

Brief Summary: Publication contains information on climate, soil conditions, planting tips, irrigation suitable for various native plant species, pest management, pruning methods and weed eradication. California Native Plant Society maintains a list of wildflower shows, native plant sales, native plant nurseries, and native garden tours.

1.6.6. Sovocool, K. A.; Rosales, J. L. & Southern Nevada Water Authority. (n.d.) **A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert**. www.snwa.com/assets/pdf/xeri_study_preliminary.pdf

Brief Summary: (from document abstract) *The authors present a selection of preliminary findings from a multiyear study quantifying the residential water and economic savings realizable by converting from traditional turf grass to xeric landscaping in a southwestern United States desert community.*

1.7. Permeable Pavements

1.7.1. Booth, D. B.; Leavitt, J. & Peterson, K. (n.d.). **The University of Washington Permeable Pavement Demonstration Project – Background and First-Year Field Results**. Center for urban Water Resources management, Department of Civil Engineering, University of Washington. Seattle, WA.

Brief Summary: This project compares the construction and performance of several porous paving systems: Geoblock, a molded plastic; Grasscrete, a cast-in-place concrete block; Geoweb, a plastic cellular confinement system; and Grasspave, another plastic confinement system.

1.7.2. Casper, B. 2006. **Streets Take Soaking at Green Development**. *SignOnSanDiego.com by the Union-Tribune*. August 13, 2006. http://www.signonsandiego.com/uniontrib/20060813/news_1h13greena.html

Brief Summary: The newspaper article describes the Pringle Creek Community Development. The streets in the development will be a narrow design and use permeable pavement.

1.7.3. Collins, K. A.;Hunt, W. F. & Hathaway, J. M. 2007, March 12-14. **Evaluation of Various Types of Permeable Pavements with Respect to Water Quality Improvement and Flood Control.** 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes a study of four permeable pavements in Kinston, NC. The preliminary runoff and water quality results are presented.

1.7.4. Dobbs, P. A.; Wright, W. C. & Tyner, J. S. 2007, March 12-14. **Exfiltration from Pervious Concrete into a Compacted Clay Soil**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes a study that compares various techniques for using pervious concrete over a clay soil. The techniques include using ripped subsoil, gravel trenches, and boreholes under the pervious concrete. As of the conference, the plots had been constructed, but no data has been collected.

1.7.5. Fassman, E. A. & Blackbourn, S. 2007, March 12-14. **Permeable Pavement Performance for Use in Active Roadways in Auckland, New Zealand**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes the demonstration of permeable pavement on a residential street in a Mediterranean climate.

1.7.6. Ferguson, Bruce. 2005. **Porous Pavement**. 1st Ed. CRC Press. Boca Raton, FL.

Brief Summary: (from abstract) The book begins with five chapters that lay a foundation for all porous pavement materials and applications, introducing the types of materials and arrangements, their roles in the urban environment, and the principles of pavement structure, hydrology, and rooting space. The following nine chapters outline the costs, maintenance requirements, advantages and disadvantages for different applications, installation methods, sources of standard specifications, and performance levels for each family of porous pavement materials.

1.7.7. Hansen, K. 2005. **Dry Parking**. *Stormwater*. S10-S14. http://www.estormwater.com/Dry-Parking-article6191

Brief Summary: The article presents construction, design, and maintenance for porous asphalt pavement with stone recharge beds.

1.7.8. Houle, J. J.; Briggs, J.; Roseen, R. M. & Ballestero, T. P. 2007, March 12-14. **Porous Asphalt Pavement: The Whole Story – Construction, Performance, Maintenance, and Myth**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes a paired comparison study of permeable asphalt and conventional asphalt in New Hampshire. In addition to cost comparisons, winter maintenance,and salt use was also compared and performance of porous asphalt as a BMP in a cold climate was assessed.

1.7.9. Hossain, M.; Scofield, L. A.; & Meier, W. R. 1992. **Porous Pavement for Control of Highway runoff in Arizona: Performance to date**. *Transportation Research Record No. 1354.*

Brief Summary: A porous asphalt section of Arizona State Route 87 was evaluated for five years. Initial permeability was 100 in/hr, and after five years of heavy traffic, the permeability was 28 in/hr. The test section showed no cracking or significant deformation

1.7.10. Hun-Dorris, T. 2005, March/April. **Advances in Porous Pavement**. *Stormwater.* http://www.erosioncontrol.com/sw_0503_advances.html

Brief Summary: The article describes the categories of porous pavements, problems and myths, and three case study examples.

1.7.11. Pratt, C. J. 1999. **Use of Permeable, Reservoir Pavement Constructions for Stormwater Treatment and Storage for Re-use**. *Water Science and Technology.* Vol 39, Issue 5, pp 145-151.

Brief Summary: The article explains the potential benefits of using permeable pavements over impermeable pavements. The article discusses the use of impermeable pavements in residential areas and potential cost savings and reduced water usage demands.

1.7.12. Sicaras, K. Victoria. 2007. **The Trickle-Down Effect**. *Public Works Magazine*. May 1, 2007.

Brief Summary: Chicago started a permeable pavement alley pilot project in the summer of 2006. Five alleys were reconstructed to test four paving models, each incorporating high-albedo concrete and either recycled concrete or permeable pavement (concrete, asphalt, or pavers) as a base material.

1.7.13. Smith, David R. 2006. **Permeable Interlocking Concrete Pavements**. 3rd ed. Interlocking Concrete Pavement Institute. Washington D.C.

Brief Summary: This reference is limited to permeable pavers. The manual lists the benefits of permeable concrete pavers, describes different types of pavers, and gives guidance on siting. It also provides a step by step

process for the design of permeable paver structures. Chapters on construction and maintenance are included.

1.8. Ponds, Wetlands, and Modified Detention Basins

1.8.1. Bautista, F. & Geiger, N. 1993, July. **Wetlands for Stormwater Treatment**. *Water Environment and Technology.* 5(7): 50.

Brief Summary: The article discusses a four year study of a constructed wetland for reducing nutrient and sediment loading. Water quality issues, criteria development, compliance, and performance evaluation are described.

1.8.2. Fox, P. & Wass, R. 1995. **Constructed Wetlands Enhances Stormwater Quality in Arizona**. *Industrial Wastewater*. March/April p. 43-46.

Brief Summary: The article describes a gravel based wetland in Phoenix, AZ used to treat parking lot runoff. The wetland requires some supplemental water, but the gravel reduces evaporation.

1.8.3. Guntenspergen, G. R.; Stearns, F. and Kadlec, J. A. 1991 **Wetland Vegetation**. in *Constructed Wetlands for Wastewater Treatment*. ed. D. A. Hammer. Lewis Publishers, Chelsea, MI.

Brief Summary: The chapter explains the biological, chemical, and physical principles for treating wastewater with constructed wetland systems. Focus is on which of over 1000 species are suitable for wastewater treatment and what are the soil-water-plant relationships.

1.8.4. Taylor, S. & Currier, B. (n.d.). **A Wet Pond as a Storm Water Runoff BMP – Case Study**. Storm Water Program. California State University, Sacramento, University of California, Davis, California Department of Transportation (Caltrans): CSUS Office of Water Programs. http://www.owp.csus.edu/research/papers/abstracts/ABSTRACTPP004CurrierArcata1999.pdf

Brief Summary: (from document abstract) *The California Department of Transportation (Caltrans) has initiated a five-year study in San Diego to examine the benefits, technical feasibility, costs, and operation and maintenance requirements of using a wet pond to treat storm water runoff from an existing freeway. The purpose of this program is to study the opportunities and constraints, relative to siting, design, construction, operation and maintenance, associated with retrofitting highways with this type of stormwater Best Management Practice (BMP) and to evaluate the efficiency of the device for removing pollutants of concern.*

1.9. Rainwater Harvesting

1.9.1. Advanced Buildings: Technologies and Practices. 2004. **Cisterns and Rainwater Harvesting Systems**. www.advancedbuildings.org/_frames/fr_t_plumbing_cisterns.htm

Brief Summary: The fact sheet contains basic and introductory information on rainwater harvesting. Case studies illustrate a variety of installation settings which utilize rainwater harvesting systems.

1.9.2. Beers, S. K. 1998, July/August. **Sourcing Water from the Sky**. *Environmental Design and Construction*.

Brief Summary: The article reviews technical considerations for designing and building a typical rainwater system and gives case studies.

1.9.3. Gould, John & Nissen-Petersen, Erik. 1999. **Rainwater Catchment Systems For Domestic Supply**. ITDG Publishing. London.

Brief Summary: (from book abstract) *The book provides a state-of-the-art review of practice in the collection of rainwater. It presents case studies with numerous examples from around the world which will help anyone intending to design or construct a rainwater catchment system.*

1.9.4. Harper, C. & Lanier, L. G. 2007, March 12-14. **Recycling Urban Stormwater: Re-Establishing the Urban Ecosystem**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation summarizes the stormwater management system used on a low rise building in downtown DC. Runoff from the site is collected in a 12,000 gallon cistern.

1.9.5. Jones, D.; Humphrey, C. & Hunt, W. F. 2007, March 12-14. **Water Harvesting and LID**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes rainwater harvesting projects and potential in North Carolina.

1.9.6. Seymour, R. M. (n.d.). **Capturing Rainwater to Replace Irrigation Water for Landscapes: Rain Harvesting and Rain Gardens**. The University of Georgia. http://www.uga.edu/water/GWRC/Papers/seymourR-GWRCpaper%20March21.pdf

Brief Summary: The paper describes the potential for rainwater harvesting and rain gardens in Georgia.

1.9.7. Stuart, D. 2001. **On-Site Runoff Mitigation with Rooftop Rainwater Collection and Use**. King County Department of natural Resources. http://depts.washington.edu/cuwrm/research/rainwater.pdf

Brief Summary: The paper describes the modeling of a rainwater harvesting system in King County, Washington.

1.9.8. Water Sensitive Urban Design in the Sydney Region. (2002c). **Practice Note 4: Rainwater Tanks**. in: *Water Sensitive Urban Design in the Sydney*

Region. http://www.wsud.org/downloads/Planning%20Guide%20&%20PN%27s/04-Rainwater%20tanks.pdf

Brief Summary: This chapter of Water Sensitive Urban Design in the Sydney Australia Region gives an overview of rainwater harvesting systems, components, regulatory issues, maintenance, and expected water savings performance.

1.10. Site Planning

1.10.1. Clayton, R. A. 2000. **Practical Tips for Construction Site Phasing**. in: *The Practice of Watershed Protection*, T. R. Scheuler and H. k. Holland (eds.). Center for Watershed Protection, Ellicott City, MD.

Brief Summary: The article describes the typical process and techniques used in phasing construction to reduce soil disturbance and erosion.

1.10.2. Coombes, Peter. 2002. **Practice Note 2: Site Planning**. *Water Sensitive urban Design in the Sydney Region.* Design and Layout by Planning Plus. http://www.wsud.org/downloads/Planning%20Guide%20&%20PN's/02-Site%20Planning.pdf

Brief Summary: This chapter of Water Sensitive Urban Design in the Sydney Region provides tips on how to sustainably plan a development site.

1.10.3. Schueler, Thomas. 1995. **Site Planning for Urban Stream Protection**. Metropolitan Washington Council of Governments: Washington D.C. http://www.cwp.org/SPSP/TOC.htm

Brief Summary: The document describes the impacts of imperviousness on water resources and a watershed approach to site planning. It also gives guidance on non-structural stormwater management, headwater streets, stream buffers, green parking lots, and other land planning topics.

1.11. Swales

1.11.1. Colwell, S. R.; Horner, R. R. & Booth, D. B. 2000. **Characterization of Performance Predictors and Evaluation of Mowing Practices in Biofiltration Swales**. *Center for Urban Water Resources Management.* Seattle: University of Washington.

Brief Summary: The swale study had two parts. The first was to develop a method for evaluating a swales status quickly. The second part was to determine the impact of mowing practices on swale performance.

1.11.2. Nara, Yukio & Pitt, Robert E. 2005. **Sediment Transport in Grass Swales**. University of Alabama, Birmingham.

Brief Summary: (from document abstract) *This paper describes another benefit of grass swales: their ability to trap particulates during low flows. A series of detailed laboratory tests were conducted to describe sediment transport processes for stormwater grass swales. Field verifications of these processes are also described in this paper.*

1.12. Vegetated Filter Strips and Riparian Buffers

1.12.1. Caltrans. 2003, Nov. **Roadside Vegetated Treatment Sites (RVTS) Study Final Report**. CTSW-RT-03-028.

Brief Summary: *The 2-year study evaluated the removal of stormwater pollutants from vegetated slopes adjacent to freeways in Sacramento, Redding, Cottonwood, San Rafael, Yorba Linda, Irvine, San Onofre, and Moreno Valley.*

1.12.2. Dillaha, T. A.; Sherrad, J. H.; Lee, D. 1986, December. **Long-Term Effectiveness and Maintenance of Vegetative Filter Strips**. Bulletin 153. http://www.vwrrc.vt.edu/publications/Bulletin%20153.pdf

Brief Summary: The 1986 study evaluates filter strips on 33 Virginia farms over 13 months.

1.12.3. Leeds, R.; Brown, L. C.; Sucl, M. R. & VanLieshout, L. (n.d.). **Vegetated Filter Strips: Application, Installation, and Maintenance.** Food, Agriculture, and Biological Engineering. Ohio State University Extension. http://ohioline.osu.edu/aex-fact/0467.html

Brief Summary: The paper presents application, installation, and maintenance issues. The document also compares eight studies of filter strips.

2. Monitoring Methods (Determination of Effectiveness)

2.1. Ackerman, Drew et al. 2003. **A Characterization of Water Quality in the Los Angeles River**. Annual Report. Southern California Coastal Water Research Project. No. 2001-2002.

Brief Summary: Study identifies potential pollution sources to the Los Angeles River. The three primary sources are water reclamation plants (3), flowing tributaries (6), and flowing storm drain outfalls (66). While nutrient levels were highest near water reclamation plant discharges, the bacteria levels were higher around the storm drain and tributary inputs.

2.2. Bachmann, N. J.; Brophy-Price, J.; Yuan, C.; Watkings, D. W. & Gierke, J. S. 2007, March 12-14. **Hydrologic Performance and Cost Analysis of an LID Stormwater Management System**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation presents a monitoring strategy of a LID system. Flow through and underdrain network was monitored.

2.3. Brown, Jeffrey & Bay, Steven. 2005**. Assessment of Best Management Practice (BMP) Effectiveness – Final Report. Technical Report.** Southern California Coastal Water Research Project. No. 461, Sep 2005.

Brief Summary: Collaborative monitoring was established with local research and stormwater management agencies that implement BMPs in the southern California coastal area. Samples of stormwater or dry weather flow from upstream and downstream of the BMP were analyzed for toxicity to aquatic life and the concentration of contaminants associated with runoff toxicity. Five BMP technologies were assessed for their effectiveness to reduce contaminant concentrations and toxicity at field sites in southern California. The sites included an enhanced stream wetland in Laguna Niguel (Wet CAT), constructed sub-surface flow wetland cells at the Orange County Water combination of screening, microfiltration, and UV treatment.

2.4. California Department of Transportation (Caltrans). Nov. 2003. **Comprehensive Protocols Guidance Manual (Stormwater Monitoring)**. CTSW-RT-03-105.51.42. http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-03-105.pdf

Brief Summary: Manual establishes uniform policies for stormwater monitoring for Caltrans. Guidance for preparing and implementing a monitoring plan are provided.

2.5. California Department of Transportation (Caltrans). 2003, Nov. **Discharge Characterization Study Report**. CTSW-RT-03-065.51.42

Brief Summary: The study characterizes stormwater runoff and pollutants from transportation facilities in California.

2.6. California State Water Resources Control Board (SWRCB). **Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance and Quality Control** *http://www.swrcb.ca.gov/swamp/qapp.html*

Brief Summary: The document describes the steps taken to ensure a high quality of data in the SWAMP program.

2.7. Forrest, C. & S. Mathews. 2002. **Construction Site Storm Water Sampling California's New Construction Sampling and Analysis Requirements**. Article submitted to 3rd Regional Conference on Erosion and Sediment Control. April 17-19. San Rafael, CA.
http://www.llnl.gov/tid/lof/documents/pdf/240175.pdf

Brief Summary: At the time of publication, few states required sampling for construction site runoff for NPDES permits. Also, California was one of the few requiring sampling of non-visible pollutants from construction site runoff. This article provides background on California regulations related to NPDES permitting and sampling and data analysis requirements. According to the authors sampling of non-visible pollutants as well as sediment related pollutants may be effective erosion and sediment control measures. The authors note that at the time of publication the sampling measures were challenged in court and future requirements may change.

2.8. Hinman, C. 2007, March 12-14. **WSU Puget Sound Low Impact Development Pilot Project Monitoring**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: A project to monitor runoff from a LID project in Western Washington was presented. The monitoring goals includes verifying that the project meets flow control regulations, determine water budgets for LID techniques, and assessing treatment performance for the project as a whole.

2.9. Horner, R.; May, C. & Livingston, E. 2004, March. **Linkages Between Watershed and Stream Ecosystem Conditions in Three Regions of the United States**. Final Report: Cooperative Agreement CX824446. Watershed Management Institute, Inc.

Brief Summary: The aquatic biological health of streams in three regions, Puget Sound, Montgomery County, MD, and Austin, TX, were compared to the human impacts on their respective watersheds. Watersheds with extremely low human development and preserved soils and native plants had the best biological health. Comparisons of urbanized watersheds with and without stormwater BMPs showed a positive impact on biological integrity in urbanized watersheds with BMPs.

2.10. Kayhanian, M. et al. 2001. **Automated Verification and Validation of Caltrans Storm Water Analytical Results.** Presented At: EPA Office of Solid Waste, Annual Waste Testing and Quality Assurance symposium, Arlington Virginia, August 16 (included in conference proceedings). http://www.owp.csus.edu/research/papers/papers/PP003.pdf

Brief Summary: Paper presents a list of recommendations or considerations for automated flow samplers.

2.11. Kayhanaian, M et. al. 2003. **The Impact of Annual Average Daily Traffic on Highway Runoff Pollutant Concentrations.** ASCE Journal of Environmental Engineering, Nov., v. 129, Issue 11, pp. 975-990. http://www.owp.csus.edu/research/papers/papers/PP037ABSTRACT.pdf

Brief Summary: This 4 year study found no direct linear correlation between annual average daily traffic (AADT) and monitored pollutant event mean concentrations (EMC), but the AADT does have an influence on most EMCs through multiple regression analysis.

2.12. Kayhanian, M. et al. 2002. **Impact of Non-detects in Water Quality Data on Estimation of Constituent Mass Loading**. Water Science & Technology Vol 45 No 9 pp 219–225. http://www.iwaponline.com/wst/04509/wst045090219.htm

Brief Summary: (from document abstract) *Often, fractions of stormwater constituents are not detected above laboratory reporting limits and are reported as non-detect. In this paper, different methods of data analysis were introduced to determine constituent mean concentrations from water quality datasets that include non-detect values. Depending on the number of non-detects and the method of data analysis, differences ranging from 1 to 70 percent have been observed in mean values. Differences in mean values were, as shown by simulation, found to have significant impacts on estimations of constituent mass loading.*

2.13. Kosco, J. et al. 2003. **Lessons Learned from In-field Evaluations of Phase I Municipal Storm Water Programs**. 2003. Presentation prepared for the 2003 National Conference on Urban Stormwater. February 17-20. Chicago, IL. www.epa.gov/owow/nps/natlstormwater03/19Kosco.pdf

Brief Summary: Kosco et al. evaluated storm water Phase I MS4 permit programs in California and selected other States. This included reviews of city and county permit programs with on-site and in-field verification. They intended to apply the lessons learned to Phase II jurisdictions. They found that pre-Phase I, programs were focused on water quantity issues. The authors suggested improving reporting, monitoring, and evaluation techniques.

2.14. Lee, G.F. & A. Jones-Lee. December 2002. **Issues in Developing a Nonpoint Source Water Quality Monitoring Program for Evaluation of the Water Quality - Beneficial Use Impacts of Stormwater Runoff and Discharges from Irrigated Agriculture in the Central Valley, CA**. Report for the California State Water Resources Control Board and the Central Valley Regional Water Quality Control Board Sacramento, California. Report TP 02-07. http://www.gfredlee.com/Agwaivemonitoring-dec.pdf

Brief Summary: The document provides goals, challenges, and recommendations for developing an non-point source water quality monitoring program. This document focuses on agricultural runoff, but it has applications to an urban runoff monitoring program.

2.15. Lee-Hung, Kim. 2006. **Estimating Pollutant Mass Accumulation on Highways during Dry Periods**. Journal of Environmental Engineering. Sept 2006, Vol. 132 Issue 9, p985-993.

Brief Summary: Two years of monitoring data from eight highway sites in southern California were used to estimate antecedent dry day pollutant loads. The results determined the 1-10 dry day antecedent pollutant buildup rates to be 0.554g/sm/day TSS, 0.114 g/sm/day COD, and 0.0113 g/sm/day for oil and grease. Buildup rates decline in subsequent period days by rates of 79% less for TSS, 78% less for COD, and 61% less for oil and grease in the following 10-70 day period.

2.16. Leecaster, MK et al. 2002. **Assessment of Efficient Sampling Designs for Urban Stormwater Monitoring**. Water Research. Vol. 36, no. 6, pp. 1556-1564. Mar 2002.

Brief Summary: A "true load" of TSS was determined for the Santa Ana River by collecting samples at nearly 15 minute intervals for every storm during the 1998 water year. The paper presents a statistical method for determining annual concentration with small sampling sizes.

2.17. Muthukrishnan, S. et al. 2004. **Chapter 5: Effective Use of BMPs in Stormwater Management**. Chapter from The Use of Best Management Practices (BMPs) in Urban Watersheds. September. EPA/600/R-04/184. Edison, NJ. (Originally cited in Finnemore, E.J. 1982. Stormwater pollution control: best management practices. Journal of Environmental Engineering Division, Proceedings of the American Society of Civil Engineers 108(EE5): 706-721.) http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap5.pdf

Brief Summary: This chapter includes the results of a case study of two sites before and after residential development in Lake Tahoe, California. The water sensitive site increased sediment loading by a factor of two and had a negligible impact on macro-invertebrates. The site without BMPs increased sediment load by factor of 107 with an observed 34% decrease in macro-invertebrate density and 54% decrease in number of macro-invertebrate species. The author concluded that implementation of BMPs and LID measures was effective in reducing suspended sediments loads.

2.18. Othmer, E.F. & B.J. Berger. 2002. **Future Monitoring Strategies with Lessons Learned on Collecting Representative Samples**. Presented at: StormCon 2002. http://www.owp.csus.edu/research/papers/papers/PP030.pdf

Brief Summary: Publication presents advantages and disadvantages to various methods of monitoring water flow and quality data.

2.19. Regenmorter, L.C. et al. 2002. **Stormwater Runoff Water Quality Characteristics from Highways in Lake Tahoe, California**. Presented at: StormCon, San Marco Island, Florida, August 12-15. http://www.owp.csus.edu/research/papers/papers/PP038.pdf

Brief Summary: The study describes the monitoring of highway stormwater runoff in Lake Tahoe, CA and the resulting data.

2.20. Schiff, Kenneth. 1997. **Review of Existing Stormwater Monitoring Programs for Estimating Bight-wide Mass Emissions from Urban Runoff**. Annual Report. Southern California Coastal Water Research Project. No. 1996.

Brief Summary: Report presents the difficulties with determining bight-wide annual pollutant load estimates to the bay. Less than 5% of the watershed areas and less than 2% of the annual runoff volumes were actually monitored during 1994-95 water year. Extrapolation of water quality data to these unmonitored channels and flows, which is necessary to develop bight-wide emission estimates, are hampered by the tremendous variability in contaminant concentrations among the different watersheds and storm events.

2.21. Shumway, R.H. et al. 2002. **Statistical Approaches to Estimating Mean Water Quality Concentrations with Detection Limits**. Environmental Science & Technology 36, no. 15: 3345-3353. http://www.owp.csus.edu/research/papers/abstracts/ABSTRACTPP039.pdf

Brief Summary: (from document abstract) *The document reviews the statistical methodology for estimating mean concentration of potentially toxic pollutants in water, for small samples that are not normally distributed and often contain substantial numbers of nondetects, i.e. samples that are only known to be below some set of fixed thresholds.*

2.22. Stormwater Monitoring Coalition's Model Monitoring Technical Committee. 2004. **Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California**. Technical Report. Southern California Water Research Project. No. 419, Aug. 2004

Brief Summary: This report describes a model monitoring program for receiving waters affected by urban runoff in both wet and dry weather. It provides a common design framework for municipal urban runoff programs and Regional Board staff to use in developing and/or revising program requirements for monitoring receiving waters for impacts, status and trends, toxicity, mass emissions, and source identification.

3. Modeling and Sizing Tools

3.1. Ackerman, D & Schiff, K. 2003. **Modeling Stormwater Mass Emissions to the Southern California Bight.** Journal of Environmental Engineering. Vol. 129, no. 4, pp. 308-317. Apr 2003.

Brief Summary: The region wide southern California study estimates mass emissions, assesses the relative contribution from urbanized watersheds, and compares pollutant flux from different land uses. A GIS based stormwater runoff model was used to estimate pollutant mass emissions based on land use, rainfall, runoff volume, and local water-quality information. 1700 storm water sampling events were used to calibrate and validate annual loadings. An average rainfall year produced 1,073x10^9 L of runoff, 118,000 metric tons of TSS, 1,940 MT of nitrate, 108 MT of zinc, and 15 kg of diazinon. The majority of mass emissions were from urbanized watersheds except for suspended solids, total DDT, and chlorpyrifos.

3.2. Anderson, Steve & Dubin, Tony. 2006. **Contra Costa County Clean Water Program Hydrograph Modification Program HSPF Modeling Guidance**. Memorandum. Brown and Caldwell. October 6, 2006.

Brief Summary: The memorandum provides technical guidance on how to build an HSPF model to evaluate the performance of hydrograph modification facilities within Contra Costa County.

3.3. Beeman, Christie & Cloak, Dan. 2005. **Hydrograph Modification Management Using Simplified Low Impact Development Design**. CASQA October, 3-5, 2005. http://www.cccleanwater.org/construction/Publications/Beeman_Christie_12D.pdf

Brief Summary: Paper describes the IMP sizing approach used by Contra Costa County Clean Water Program. Simplified design guidelines, standard design details, specifications, and sizing factors, allow development applicants to easily incorporate IMPs.

3.4. Beyerlein, Douglas. 2007. **Memorandum: Comparison of Contra Costa IMP and BAHM/WWHM3/HSPF**. Memorandum from Clear Creek Solutions. April 2, 2007.

Brief Summary: The memo compares and contrasts the Contra Costa IMP Sizing Tool, BAHM, WWHM3, and HSPF.

3.5. Bicknell, Jill; Beyerlein, Doug & Feng, Arleen. 2006. **The Bay Area Hydrology Model – A Tool for Analyzing Hydromodification Effects of Development Projects and Sizing Solutions**. CASQA Conference. September 26, 2006. http://scvurppp-w2k.com/permit_c3_docs/Bicknell-Beyerlein-Feng_CASQA_Paper_9-26-06.pdf

Brief Summary: BAHM is a cooperative venture of three stormwater programs: Southern San Francisco Bay area, the Santa Clara Valley Urban Runoff Pollution Prevention Program, the Alameda Countywide Clean Water Program and the San Mateo Countywide Stormwater Pollution Prevention Program. Similar to the Western Washington Hydrology Model, the BAHM will automatically size facilities to match the pre- and post-project flow duration curves, thus allowing project applicants and agency staff to meet the requirements of the Bay Area HMPs. *This paper describes the background and need for the BAHM, development of the BAHM and appropriate parameters for the southern Bay Area, and examples of application of the tool to size hydromodification control facilities for two development projects.*

3.6. Burian, SJ et al. 2001. **Modeling the Atmospheric Deposition and Stormwater Washoff of Nitrogen Compounds.** Environmental Modelling & Software with Environment Data News [Environ. Model. Software Environ. Data News]. Vol. 16, no. 5, pp. 467-479.

Brief Summary: The CIT airshed model and the USEPA SWMM were combined to model nitrogen pollution in Los Angeles from the air through the watershed and into Santa Monica Bay.

3.7. Burian, SJ. 2002. **Modeling the Effects of Air Quality Policy Changes on Water Quality in Urban Areas**. Environmental Modeling and Assessment. Vol. 7, no. 3, pp. 179-190. Sep 2002.

Brief Summary: Paper describes an integrated modeling framework composed of an urban air chemistry model, an urban runoff model, and a water-quality model. The model linkage is demonstrated by evaluating the potential water quality implications of reducing from 1987 air pollutant levels to proposed 2000 target levels in Los Angeles, California, USA. Simulations of the Los Angeles dry season during the summer of 1987 (June 1 to August 31) indicated that by reducing emissions from 1987 to proposed year 2000 levels, the dry deposition nitrogen loads to Santa Monica Bay and the Ballona Creek watershed were reduced 21.4% and 15.0%, respectively.

3.8. Cheng, M. S.; Akinbobola, C. A. & Zhang, Y. 2007. **BMP Decision Support System for Evaluating Watershed-based Stormwater Management Practices**. 2nd National Low Impact Development Conference. March 12-14, 2007.

Brief Summary: The presentation describes the BMP Decision Support System, a PG County BMP Model extension to ArcGIS.

3.9. Geosyntec Consultants. 2007. **Aliso Creek Inn & Golf Course Redevelopment Project: Water Quality Technical Report.** Prepared for the Athens Group. March 2007.
http://64.58.157.203/government/departments/alisocreekplan.htm

Brief Summary: A proposed redevelopment for the Aliso Creek Inn & Golf Course in Laguna Beach, CA will add vegetated swales, cisterns, and golf course sand caps. The report summarizes the stormwater runoff volume and pollutant load modeling method.

3.10. Ha, H & Stenstrom, MK. 2003. **Identification of Land Use with Water Quality Data in Stormwater using a Neural Network**. Water Research. Vol. 37, no. 17, pp 4222-4230. Oct 2003.

Brief Summary: The research proposes a neural network approach to examine the relationship between stormwater quality and various types of land use. The neural network model can be used to identify land-use types for future known and unknown cases.

3.11. Horner, R.R. 2006. **Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Diego Region**. University of Washington Departments of Civil Engineer and Landscape Architecture, Center for Urban Horticulture.
http://www.projectcleanwater.org/pdf/permit/case-study_lid.pdf

Brief Summary: Study compares six land use types in San Diego with no BMPs, traditional BMPs, and LID treatment. The six generic land development types used were multi-family residential, small-scale single-family residential, restaurant, office building, large-scale single-family residential and retail commercial. The traditional BMPs, those commonly used by developers currently, are catch basin inserts, CDS devices, and other manufactured BMPs. The LID approach outperformed the traditional BMPs in pollutant removal. The LID analysis also showed that three of the development types, small-scale single family, restaurant, and office building, could infiltrate all of the runoff in an average year. If roof rainwater was harvested, then all of the development types can potentially infiltrate all of the runoff in an average year.

3.12. Jarrett, A. R.; Hunt, W. F. & Berghage, R. D. 2007, March 12-14. **Evaluating a Spreadsheet Model to Predict Green Roof Stormwater Management**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: A spreadsheet was used to model stormwater retention by a green roof through the course of a year.

3.13. Job, S. 2007, March 12-14. **Applications of the Site Evaluation Tool, a Site-Scale Development Impacts Model**. Tetra Tech, Inc. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: Tetra Tech developed the Site Evaluation Tool to quickly evaluate development impacts. Several case studies from North Carolina and one from Arkansas are used to demonstrate the spreadsheet tool.

3.14. Low Impact Development Center. **Stormwater Management Model (SWMM) Analysis Report: Metro West**. October 1, 2005. Fairfax County, VA.

Brief Summary: Four conditions for a 63.93 ac. site in Fairfax County, VA were modeled using the Stormwater Management Model: wooded, existing (low density), redeveloped medium to high density residential and commercial, and redeveloped with LID. The scenarios were modeled for single event storms and continuous 1992 rainfall. The limited use of LID reduced runoff volume by about a quarter from the developed condition.

3.15. McPherson, Timothy N. 2005. **Trace Metal Pollutant Load in Urban Runoff from a Southern California Watershed**. Journal of Environmental Engineer. July 2005 Vol. 131Issue 7, p1073-1080

Brief Summary: Monitoring data and modeling for Ballona Creek in Los Angeles, CA determined pollutant contributions for wet weather and dry weather flows from 1991 to 1996. Approximately 9-25% of the total annual Ballona Creek flow volume is DWF. The simulation indicates DWF accounts for 54, 19, 33, and 44% of the average annual load of total chromium, copper, lead, and nickel, respectively. Study emphasizes the importance of mitigation for dry weather flows.

3.16. Park, M & Stenstrom, MK. 2005. **A New Classification System for Urban Stormwater Pollutant Loading: A Case Study in the Santa Monica Bay Area**. Journal of Water and Environment Technology. Vol. 3, no. 2, pp. 191-197.

Brief Summary: Article describes a method of estimating pollutant loads for a large area in time and cost effective way. Satellite imagery was used to directly estimate pollutant loadings as opposed to translating the satellite imagery into land use and then estimating pollutant loading from land use data. Marina del Rey area in the Santa Monica Bay Watershed was used as a case study. The results are useful in developing management practices for stormwater runoff.

3.17. Sayre, J. M., J. S. Devinny, J. P. Wilson, & Yan, Xiaoxu. 2006. **Green Visions Plan for 21st Century Southern California. 12. Neighborhood Stormwater**

Quality Modeling. University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California. http://www.greenvisionsplan.net/html/publications.html

Brief Summary: Provides summaries of stormwater models that can be used to model stormwater in urban neighborhoods of southern California.

3.18. Strecker, Eric & Hesse, Todd. **Pelican Hills Resort – A Low Impact Approach in Southern California**. Powerpoint Presentation. EWRI 2005: Impacts of Global Climate Change Conference.

Brief Summary: An LID stormwater management plan was used to maintain pre-development hydrology for resort. A combination of catch basin inserts, biofiltration, cisterns, and water quality basins, as well as source controls, were included in the management plan. The SWMM model was used with 40 year continuous rainfall.

3.19. US Environmental Protection Agency. July 2006. **BMP Modeling Concepts and Simulation**. EPA/600/R-06/033 http://www.epa.gov/nrmrl/pubs/600r06033/epa600r06033toc.pdf

Brief Summary: The document provides detailed information on how various stormwater models simulate BMPs. Recommendations on how to improve SWMM's ability to model LID are given.

3.20. USGS (United States Geologic Survey). 2005. **Source Loading and Management Model (SLAMM): An Urban Area Nonpoint Source Water Quality Model**. http://wi.water.usgs.gov/slamm

Brief Summary: The webpage provides information about the SLAMM model and links to additional information. *(from the website) SLAMM was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality…..now includes a wide variety of source area and outfall control practices….strongly based on actual field observations, with minimal reliance on theoretical processes which have not been adequately documented or confirmed in the field. SLAMM is used mostly as a planning tool… however SLAMM can be effectively used in conjunction with drainage design models to accurately predict stormwater flows and pollutant characteristics for a broad range of rains, development characteristics and control practices*.

3.21. Wilkerson, G.W.; McAnally, W. H.; Marin, J. L. et al. 2007, March 12-14. **Latis A Spatial Decision Support to Assess low Impact Site Development Strategies.** Mississippi State. 2nd National Low Impact Development Conference.

Brief Summary: An HSPF model, ArcView, and excel worksheets were used to develop a hydrologic modeling process for evaluating LID site design. A commercial site in Mississippi was used as a case study.

4. Planning & Smart Growth

4.1. Ben-Joseph, E. 2004. **Double Standards, Single Goal: Private Communities and Design Innovation.** Journal of Urban Design. June. Vol. 9 No. 2, 131-151. http://web.mit.edu/ebj/www/JUDStandards.pdf

Brief Summary: In Southern CA, particularly Los Angeles and San Diego, greater than 60% of all new housing is now built under the governance of neighborhood associations. Public domain regulations often restrict alternative solutions, i.e. Street width, setbacks, stormwater conveyance. Common interest communities, private subdivisions, or private domain development provide opportunities for simplified approval process and the introduction of design innovation.

4.2. Bina, Arash and Devinny, Joseph. 2006. **The Green Vision Plan for 21st Century Southern California: 10. Stormwater Quality Control Through Retrofit of Industrial Surfaces**. University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California.

Brief Summary: This segment of the Green Visions Plan presents two approaches to addressing stormwater runoff from industrial sites in Los Angeles region. One approach is to create partnerships with industry and build site BMP retrofits. The other approach is to purchase sites that could remediate stormwater from a much larger watershed in a manner compatible with public use such as wildlife habitat or recreational park.

4.3. Kloss, C & Calarusse, C. 2006, June. **Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows**. Natural Defense Council.

Brief Summary: The document discusses various green strategies for limiting or eliminating combined sewer overflows (CSOs) and MS4 problems . Nine city case studies in North American cities which employ various source controls and regulatory structures are reviewed.

4.4. Lloyd, S. D., Wong, T. H. F. & Porter, B. (n.d.). **The Planning and Construction of an Urban Stormwater Management Scheme**. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11989883&dopt=Abstract

Brief Summary: (from document abstract) *Water Sensitive Urban Design (WSUD) offers a means to integrate stormwater best management practices into urban planning and design to achieve multiple objectives. Some of these objectives relate to stormwater drainage, water quality improvements, aquatic habitat protection, stormwater harvesting and use, and landscape amenity.*

4.5. Shapiro, N. 2003. **The Stranger Amongst Us: Urban Runoff, The Forgotten Local Water Resource**. Presentation prepared for the 2003 National Conference on Urban Stormwater. February 17-20. Chicago, IL. http://www.epa.gov/owow/nps/natlstormwater03/33Shapiro.pdf

Brief Summary: Shapiro details the goals of the City of Santa Monica's watershed-urban runoff management approach. This includes the use of LID techniques, as required by City ordinance. The goals will be accomplished by stormwater runoff harvesting from new development, dry weather and wet weather urban runoff treatment within City boundaries, and dry weather runoff recycling.

4.6. Stahre, Peter. 2006. **Sustainability in Urban Storm Drainage: Planning and Examples**. Svenskt Vatten. January 2006

Brief Summary: The book provides an introduction to LID, planning guidance, and European LID project examples.

4.7. Wildman, N. 2007, March 12-14. **Sustainable Cities: Using LID Principles for Sustainable Hydrology on Urban Sites**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: Presentation presents the definition and scales of sustainability through the lens of stormwater management. Details projects which are implemented at the site scale but achieve benefits at the watershed scale.

5. Economic

5.1. Braden, John B.; Johnston, Douglas H. & Price, Thomas H. 2004. **Downstream Economic Benefits of Conservation Development**. Prepared for Conservation Research Institute, Elmhurst, IL. http://www.bayoupreservation.org/pages/articles/Johnston%20et%20al.pdf

Brief Summary: The study compares the downstream economic benefits of using conservation development over conventional development in Kane County, IL. The downstream benefits considered were reduced flooding and infrastructure upgrades or replacements. A cost analysis of conventional and conservation designs for each moderate density residential, rural residential, estate residential, commercial/industrial land uses were compared.

5.2. Brown, W. & Schueler, T. 1997. **The Economics of Stormwater BMPs in the Mid-Atlantic Region**. Prepared for: Chesapeake Research Consortium. Edgewater, MD. Center for Watershed Protection. Ellicott City, MD. http://www.cwp.org/Downloads/ELC_swbmp.pdf

Brief Summary: The report presents cost estimates and prediction equations for commonly used BMPs in the Mid-Atlantic Region.

5.3. Carter, Timothy Lynn. 2003. **An Economic Analysis of Green Roof Systems**. Unpublished. University of Georgia.

Brief Summary: The author presents an economic analysis of green roof systems.

5.4. Conservation Research Institute. 2005. **Changing Cost Perceptions: An Analysis of Conservation Development**. Report prepared for Illinois Conservation Foundation and Chicago Wilderness.

Brief Summary: The study shows the economic benefits of using conservation development over conventional development in Kane County, IL through a literature review, an analysis of built-site case studies, and a cost analysis of hypothetical conventional and conservation design templates or layouts.

5.5. Coombes, P. & Kuczera, G. (2000, April 30). **Tank Paddock: A Comparison Between Traditional and Water Sensitive Urban Design Approaches**. University of Newcastle. http://www.eng.newcastle.edu.au/~cegak/Coombes/TPaddReport.htm

Brief Summary: Costs and stormwater management performances were compared for a traditional and water sensitive urban design at the Tank Paddock, Newcastle, UK. The WUSD development had significant cost, volume discharge, and stormwater peak reductions.

5.6. Dewoody, Autumn; Cutter, W. Bowman and David Crohn. 2006. **Costs and Infiltration Benefits of the Watershed Augmentation Study Sites**. University of California, Riverside, Department of Environmental Sciences. April 17, 2006.

Brief Summary: Five case study sites retrofitted with BMPs are modeled using WinSLAMM. Costs per annual volume infiltrated are calculated for each scenario. Maintenance costs for each of the sites are also calculated and compared.

5.7. Ewing, Reid; Heflin, Christine C.; DeAnna, MaryBeth; and Porter, Douglas R. 1995. **Best Development Practices: Doing the Right Thing and Making Money at the Same Time**. Joint Center for Environmental and Urban Problems. Florida Atlantic University/Florida International University.

Brief Summary: The book draws best practice recommendations from case studies of acclaimed developments. The book shows how developers can follow these best management practices and still be profitable.

5.8. Fan, C-Y; Field, R; Lai, F-h; Heaney, et al. 2000. **Cost of Urban Stormwater Control**. Joint Conference on Water Resources Engineering and Water Resources Planning and Management. Minneapolis, MN, Americon Society of Civil Engineers. (CD Rom)

Brief Summary: The paper reviews cost studies and cost estimating models on urban stormwater controls. The paper then identifies cost information gaps and research needs.

5.9. Farnsworth, Christina B. 2003, October. **Dollars & Sense: Cut Development Costs and Generate Higher Lot Premiums with Conservation Design**. *Builder*. Pp. 244-250.

Brief Summary: The article describes how residential developer, Bielinski Homes, has attained higher prices for homes in developments with conservation design.

5.10. Ferguson, Timothy; Gignac, Robert; Stoffan, Mark; Ibrahim, Ashraf; & Aldrich, John. 1997, July 7. **Cost Estimating Guidelines: Best Management Practices and Engineered Controls**. 1st Edition. Rouge River National Wet Weather Demonstration Project. Wayne County, Michigan.

Brief Summary: The development guide provides design criteria and cost estimates for 23 categories of BMPs.

5.11. Fisher, H.; Burkhart, B. & Brebner, A. 2007, March 12-14. **LID on the SC Coastal Plain: Benefits, Costs, and Constraints**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The project evaluates costs and benefits of two case studies in South Carolina using the Site Evaluation Tool (SET). One case is a comparison of single family neighborhood development and the other is a multifamily development comparison of LID vs. conventional development..

5.12. Greenroofs.com. 2003. **Exploring the Ecology of Organic Greenroof Architecture: Economic Advantages**. http://www.greenroofs.com/Greenroofs101/economic.htm

Brief Summary: The website lists potential cost savings from greenroofs. Other sections of the website list ecological, aesthetics and psychological advantages of green roofs.

5.13. Hitzhusen, F. J.; Haab, T.; Sohngen, B.; Kruse, S. & Abdul-Mohsen, A. 2007, March 12-14. **Willingness to Pay for Low Impact Development Environmental Benefits**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: This research from Ohio State University is a classic cost benefit analysis of LID on a watershed scale in river corridors.

5.14. Howard, R. & N. Strawn. 2001. **Water facility keeps beaches clean**. Jul 2001. The American & County. July, Vol. 116, Iss. 9, pg. 4. http://www.feinstein.org/americancity&country/cleanwater.html & http://md1.csa.com/partners/viewrecord.php?requester=gs&collection=TRD&recid=05207496EN&q=&uid=790610934&setcookie=yes

Brief Summary: Santa Monica Urban Runoff Recycling Facility (SMURRF) is a centralized urban runoff treatment train: screens, grit chamber, flow equalization, air flotation, microfiltration, and ultraviolet light disinfection. Facility has a capacity 0.5 million gal/day and cost 12 million dollars. This example of a centralized stormwater treatment system could be used as a comparison to a decentralized LID approach.

5.15. Liptan, T. & Brown, C. K. 1996. **A Cost Comparison of Conventional and Water Quality-Based Stormwater Designs**. City of Portland. Bureau of Environmental Services. Portland, OR.

Brief Summary: The publication compares the costs for conventional and LID stormwater management. The study showed that a residential development in Davis, CA provided an estimated infrastructure cost savings of $800 per home.

5.16. Lloyd, S.D. (n.d.). **Quantifying Environmental Benefits, Economic Outcome and Community Support for Water Sensitive Urban Design**. *Cooperative Centre for Catchment Hydrology & Department of Civil Engineering, Monash University.* www.wsud.org/downloads/Info%20Exchange%20Exchange%20&%20Lit/Lloyd%20 2004%20_final%20paper.pdf

Brief Summary: Paper describes an economic investigation in Melbourne, Australia. The investigation found that a decentralized bio-filtration system provided 25% savings over a conventional development with a centralized downstream constructed wetland treatment system.

5.17. MacMullan, Ed. 2007, March 12-14. **Using Benefit Cost Analyses to Assess LID**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: Presentation advocates for a more complete cost-benefit analysis of LID. A complete economic comparison of conventional and LID approaches includes installation costs, operation and maintenance costs, and economic benefits.

5.18. Montgomery, James. May 1992. **A Study of Nationwide Costs to Implement Municipal Stormwater Best Management Practices.** Consulting Engineers, Inc. OCLS: 26523227.

Brief Summary: The study examines the costs of implementing municipal stormwater BMPs nationwide.

5.19. Moore, JE II et al. 2004. **Cost Analysis Methodology for Advanced Treatment of Stormwater: The Los Angeles Case**. Journal of Construction Research. Vol. 5, no. 2, pp. 149-170. Sept 2004.

Brief Summary: A methodology for estimating costs for stringent stormwater treatment and operation as well as an estimated city and regional economic impacts are presented. This case-study based research presents nine different cost analysis scenarios based on different strategies for determination of rainfall, location of plants, and size of plants. The cost and size of the new collection and treatment facilities increases substantially if they are designed to accommodate a larger share of expected annual rain events. It will cost about six times more to build a system that can treat storm flows from 97% of the region's annual average storm days than it would to build to a 70% standard. This additional cost achieves about nine additional days of storm flow coverage.

5.20. Powell, L. M.; Rohr, E. S.; Canes, M. E.; Cornet, J. L.; Dzuray, E. J. & McDougle, L. M. 2005. **Low-Impact Development Strategies and Tools for Local Governments. Building a Business Case**. LMI Government Consulting. September 2005. http://lowimpactdevelopment.org/lidphase2/pubs/LMI%20LID%20Report.pdf

Brief Summary: The report provides a background and procedure for municipal managers to conduct life cycle cost analysis on LID projects.

5.21. Rein, Felicia A. 1999. **An Economic Analysis of Vegetative Buffer Strip Implementation Case Study: Elkhorn Slough, Monterey Bay, California**. *Coastal Management* 27:377-390.

Brief Summary: The study investigates the environmental costs and benefits for vegetated buffer strips.

5.22. Southeast Wisconsin Regional Planning Commission. 1991. **Costs of Urban Nonpoint Source Water pollution Control Measures**. Technical Report No. 31. Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

Brief Summary:

5.23. Weinstein, N; Lampe, L.; Andrews, H; Barrett, M.; Glass, C.; Jefferies, C.; Martin, P. & Woods-Ballard, B. 2004. **Post-Project Monitoring of BMPs/SUDs to Determine Performance and Whole-Life Costs.** Water Environment Research Foundation (WERF)

Brief Summary: Capital and maintenance costs for 6 types of BMPs are estimated. The whole life costs of the BMPs are modeled.

5.24. Zielinkski, Jennifer; Caraco, Deb & Claytor, Rich. July 2000. **Comparative Nutrient Export and Economic Benefits of Conventional and Better Site Design Techniques**. Conference on Tools for Urban Water Resources Management & Protection. Proceedings. EPA/625/C-00/001.

Brief Summary: Conference proceedings contain information on nutrient export and the economic benefits of LID design techniques.

6. Manuals of Practice

6.1. Bay Area Stormwater Management Agencies Association (BASMAA) Manuals (Design Guidelines 1999 and 2005) found at: http://www.basmaa.org/documents/index.cfm?fuseaction=documents&doctypeID=3

Brief Summary: The BASMAA contains links to many site design groups, BMP manuals, and other LID related materials.

6.2. California Stormwater Quality Association (CASQA). 2003. **Stormwater BMP Handbooks**.
http://www.cabmphandbooks.com/

Brief Summary: There are four handbooks directed to different audiences:
- New development and redevelopment
- Construction
- Industrial and commercial
- Municipal

6.3. Emeryville, City of. December 2005. **Stormwater Guidelines for Green, Dense Redevelopment.** Prepared by Community Design + Architecture *with* Nelson\Nygaard Consulting Associates and Philip Williams Associates.
http://www.ci.emeryville.ca.us/planning/pdf/stormwater_guidelines.pdf

Brief Summary: This manual from Emeryville, CA provides guidelines for green development.

6.4. Hinman, Curtis. 2005, January. **Low Impact Development Technical Guidance Manual For Puget Sound**. Puget Sound Action Team and Washington State University. Olympia, WA.
http://www.psat.wa.gov/Publications/LID_tech_manual05/LID_manual2005.pdf

Brief Summary: The manual provides an introduction to LID and how to design BMPs to meet Washington Department of Ecology guidelines. The manual also describes how to model LID in the Western Washington Hydrology Model.

6.5. Kennedy/Jenks Consultants. 2005. **Truckee Meadows, NV Low Impact Development Handbook: Guidance on LID Practices for New Development and Redevelopment.** http://www.cityofreno.com/Index.aspx?page=996

Brief Summary: LID Manual for the Reno, NV area

6.6. Portland, City of. 2004. **Stormwater Management Manual, Portland, OR.** Bureau of Environmental Services.

Brief Summary: LID Manual for Portland, OR

6.7. Sacramento, City and County of. 2000. **Guidance Manual for Onsite Stormwater Quality Control Measures.** Sacramento Stormwater Management Program.

Brief Summary: LID Manual for Sacramento City and County, CA

6.8. Salinas, City of. 2007. **City of Salinas Development Standards Plan Low Impact Development.** Central Coast Regional Water Quality Control Board. DRAFT.
http://www.waterboards.ca.gov/centralcoast/stormwater/municipal/phase_1/salinas_lid_index.htm

Brief Summary: LID Manual for Salinas, CA

6.9. San Diego County, Department of Planning and Land Use. 1998. **Landscape Water Conservation Design Manual**. http://www.sdcounty.ca.gov/dplu/Resource/docs/3~pdf/LandWtrConMan_sm.pdf

Brief Summary: Manual includes codes on water conservation irrigation and plantings. The manual also includes a list of native plants.

7. *Training and Outreach Materials*

7.1. Anonymous. 1999. **LA targets polluters with ad campaign**. Jun 1999. The American City & County. June 1. http://americancityandcounty.com/mag/government_la_targets_polluters/

Brief Summary: Los Angeles County Department of Public Works concluded a $1 million four-month campaign to remind area residents of steps to prevent stormwater pollution and flooding. The campaign focused on four sources: 1. litter from street, sidewalks, and parking lots, 2. animal waste, 3. fertilizer, and 4. pesticides.

7.2. Gleick, P.H. et al. 2003. **Waste Not, Want Not: The Potential for Urban Water Conservation in California**. Pacific Institute for Studies in Development, Environment, and Security (Ed. N. L. Cain). November. Oakland, CA. http://www.earthscape.org:80/p1/ES16450/waste_not_want_not.pdf

Brief Summary:

7.3. Low Impact Development Center. 2006, August. **Low Impact Development Training for Western Developers: Supplemental Material**. EPA Assistance Agreement AW-83255301.

Brief Summary: (from document abstract) *This document presents information that is intended to assist developers in meeting their stormwater management goals. The report is designed to explain the mechanics of low impact development best management practices (LID BMPs) and how they can be applied throughout the planning, permitting, building and occupancy phases of development.*

7.4. Mull, K. K. 2005, December. **Selling Low Impact Development: Audiences, Messages, and Media.** Fourth National Nonpoint Source and Stormwater Pollution Education Programs (46-52). Chicago: Holiday Inn http://www.epa.gov/owow/nps/2005_nps_outreach_proceedings.pdf

Brief Summary: Conference proceedings contain many LID education outreach case studies.

7.5. New England Environmental Finance Center. (n.d.). **Promoting Low Impact Development in Your Community**. Report Series #06-05

Brief Summary: Document provides recommendations on how to present and promote LID to communities. It also provides links to other training

8. *Pilot Projects*

8.1. Anonymous. 2007. **Taking trash out of runoff**. The American City & County. February. Vol. 122, Iss. 2, pg 43.

Brief Summary: Filter system designed by Kansas City, MO based Black & Veatch was built beneath Mar Vista Park in Santa Monica. The facility will remove trash and sediment from runoff to a tributary of Santa Monica Bay.

8.2. Anonymous. 1995, December. **Flood Control Project Results in Children's Park**. *The American City & County*.

Brief Summary: Fresno-Clovis metropolitan area stormwater management uses large flat shallow infiltration basins. Five basins are outfitted as playgrounds and 12 serve as passive parks. The system on average, captures and recharges to groundwater 31,500 acre-feet of rainfall runoff, equaling 90 percent of all area stormwater runoff.

8.3. Brennan, Pat. 2007. **Saving Precious Drops: Project Shows How Homeowners Waste Water**. *Orange County Register.* June 18, 2007

Brief Summary: Three small almost identical faux houses were set up on an Orange County agricultural research station to demonstrate typical, retrofitted, and low impact water use and runoff management systems. Pesticide migration off the residential sites will also be monitored. Initially, the program will run two years, ending in 2009.

8.4. Feinbaum, R. 2004. **Bringing Sustainability to Los Angeles**. *Biocycle*. July. Vol. 45, Iss. 7. pg. 29-31.
http://www.jgpress.com/inbusiness/archives/_free/000637.html

Brief Summary: As an alternative to an expensive storm drain, county officials and TreePeople developed a watershed management plan for Sun Valley focusing on stormwater mitigation, retention, recharge, and reuse. In spring of 2004, in another project, TreePeople demonstrated a home site in South Central Los Angeles could hold and store all the water from a violent storm. Two tons of water was poured on the roof of a house. A cistern collection system, vegetated swale with retention grading, redirection of downspouts, and a drywell were used to retain water. TreePeople have also created the TreePeople Center for Community Forestry in Coldwater Canyon Park, a platinum level green building council development. The Center has a shaded partially porous parking lot, vegetated swale, and a 250,000 gallon cistern.

8.5. Lantz, C. & Weinstein, N. 2007, March 12-14. **Fort Bragg LID Pilot Projects**. 2nd National Low Impact Development Conference.
http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: This presentation describes a bioretention pilot project on a Fort Bragg, SC ; the project is a retrofit in a parking lot in a SE Coastal Plain setting.

8.6. Sicaras, Victoria. **The Trickle-Down Effect**. Public Works Magazine Online. May 2007.

Brief Summary: Chicago, with more than 1900 miles of alleys, has undertaken a "green alleys" pilot project. Five alleys with maintenance problems and ideal soil conditions were redeveloped to test four paving models. In addition to reducing flooding problems, the "green alleys" will reduce heat island effects and use recycled materials.

9. Institutional and Program Development (Corporate and Government)

9.1. Hubble, S. 2007, March 12-14. **Implementation of a Local LID Program: Case Study, Stafford County Virginia.** 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes how Stafford County, VA has removed barriers to LID projects and incorporated LID into their stormwater management ordinance.

9.2. Olympia, City of and Thurston County. 2002. **Low Impact Development Strategy for Green Cove Basin: A Case Study in Regulatory Protection of Aquatic Habitat in Urbanizing Watersheds.** Olympia: City of Olympia Water Resources Program. www.psat.wa.gov/Programs/LID/Green_Cove.pdf

Brief Summary: Paper provides a case study summary of incorporating LID standards into municipal development regulations. Paper gives advice to other jurisdictions adopting LID standards.

9.3. Tackett, T. March 12-14 2007. **Street Alternatives: Seattle Public Utilities' Natural Drainage System Program**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: The presentation describes the Street Alternatives Program.

10. Stakeholder Effort

10.1. Condon, P. & Moriarty, S. (eds). **Second Nature: Adapting LA's Landscape for Sustainable Living**. TreePeople, Beverly Hills. 1999.

Brief Summary: The book comes from a sustainable landscape design for the Los Angeles region charrette. Specific proposals for redesigns and retrofits are offered for single-family homes, multi-family home, public, commercial, and industrial.

10.2. Kennedy, L. & Holmes, L. 2006. **Going Green: How To Incorporate Stakeholders' Values For Sustainability**. Presented at Water Environment

Federation Technical Exhibition and Conference (WEFTEC). Carollo Engineers. Walnut Creek, CA. http://environmental-expert.com/Files%5C5306%5Carticles%5C9271%5C219.pdf

Brief Summary: (from document abstract) *Stakeholders and public interest groups are increasingly calling for sustainability to serve as a guiding principle for water and wastewater management decisions. For the San Francisco Sewer System Master Plan (SSMP), Carollo Engineers surveyed water and wastewater utilities to learn whether and how they incorporated sustainability into their planning processes, and conducted a literature review on sustainability indicators. This paper presents a summary of the survey and literature review, as well as a description of how that information is being integrated into the SSMP.*

10.3. Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and Santa Clara Basin Watershed Management Initiative's (SCBWMI) Land Use Subgroup. 2004, Fall. **Understanding Potential Hurdles to Using Better Site Designs for Water Quality Protection: A First Step Towards Resolving Conflicts, Real or Imaginary**. From SCVURPPP. http://www.scvurppp-w2k.com/site_design_dialogues.htm

Brief Summary: The website contains powerpoints and summaries from a *four-part series of dialogues designed to develop a deeper understanding of issues needed to successfully incorporate better site designs into new and redevelopments.* The issues discussed included fire department & public safety concerns, drainage to landscaping, reducing building footprints, reducing the parking foot print, and structural soils.

10.4. Swamikannu, X. 1998. **An Integrated Strategy for Managing Urban Runoff Pollution in Los Angeles County.** Taking a Look at California's ocean Resources: An Agenda for the Future. Vol. 2, pp. 876-887. 1998.

Brief Summary: As part of the county NPDES permit, Los Angeles county staff utilized consensus-building techniques and worked with a committee of stakeholders (the "negotiating group") comprised of representatives of selected municipalities and environmental groups. The paper describes the process followed to reach agreement on this effort, the progress to date, and challenges ahead.

10.5. TreePeople – Los Angeles Area Non-Profit Organization. http://www.treepeople.org/

Brief Summary: TreePeople is an active non-profit LA stakeholder with many LID related initiatives.

11. Regulatory

11.1. **Federal**

11.1.1. Federal Water Pollution Control Act. **"Clean Water Act."** 33 U.S.C 1251 et seq. http://www.epa.gov/region5/water/cwa.htm

Brief Summary: The CWA established the statutory authority to regulate discharges to navigable waters of the U.S. The 1987 amendments created a mandate to regulate stormwater, which has been defined as a point source discharge subject to NPDES permitting.

11.2. State

11.2.1. California Department of Transportation (Caltrans). May 2003. **Statewide Stormwater Management Plan**. CTSW-RT-02-008. http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-02-008.pdf

Brief Summary: Administration of NPDES program is delegated to State Water Resources Control Board (SWRCB) and nine (9) Regional Water Quality Control Boards (RWQCBs).

11.2.2. California State Water Resources Control Board. 2007. **Draft General NPDES Permit for Construction Activities.** Order No. 2007 - XX – DWQ, General Permit No. CAR000002.

Brief Summary: The draft permit, for the first time, contains provisions for post-construction runoff control stipulating that post-construction runoff volumes and time of concentration approximates pre-construction values. This regulatory approach attempts to limit site hydromodification rather that only discharge rates.

11.2.3. CA State Water Resources Control Board. 2007, March. **Draft National Pollutant Discharge Elimination General System General Permit Number CAR000002, Waste Discharge Requirements for Discharges of Stormwater Runoff Associated with Construction Activity**.

Brief Summary: This proposed General NPDES permit will include discharge requirements on construction activity and post-construction controls.

11.2.4. CA Storm Water Panel. 2006. **The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial, and Construction Activities**. Storm Water Panel Recommendations to the California State Water Resources Control Board. June 19. http://www.cacoastkeeper.org/assets/pdf/StormWaterPanelReport_06.pdf

Brief Summary: This report describes the process of regulatory and permit review to determine the feasibility of assigning numeric effluent limits applicable to discharges in three categories of development: municipal, construction and industrial. Draws on examples of Oregon process and identifies need to adjust standards to fit local conditions and seasonal variations. Outlines a process by which progress towards numeric standards may be made without unduly penalizing California industries.

11.2.5. California, State of. 1990. **Water Conservation in Landscaping Act of 1990**. California Codes, Government Code Section 65591-65600. Updated 2004 (AB 2717), Updated 2007 (AB 1881).

Brief Summary: The Act includes code for landscape design, installation, and maintenance that is water efficient.

11.2.6. Maryland, State of. 2007. **Maryland Stormwater Management Act of 2007, Senate Bill 784 / House Bill 786** http://mlis.state.md.us/2007RS/billfile/sb0784.htm

Brief Summary: The Maryland Stormwater Management Act stipulates that Environmental Site Design (ESD) using LID practices is the preferred stormwater control method in the State and must be utilized as the first control option for new development projects. Only after the developer or designer can demonstrate that they have used ESD to the maximum extent practicable are they permitted to use conventional stormwater controls. This is a hybrid regulatory approach using a traditional command-and-control regulatory construct that inherently is flexible because of the expansive list of allowable LID BMPs and techniques.

11.2.7. New Jersey, State of. 2004. **Stormwater Management Rule.** New Jersey Register, N.J.A.C., Vol. 7, No. 8, Feb. 2, 2004

Brief Summary: New Jersey's Stormwater Management Rule was a departure from the conventional peak flow control stormwater requirements. The 2004 rule stipulated as the primary control criteria that post-development hydrographs replicated pre-development hydrographs for each and every point in time and that pre-development recharge rates be maintained. This regulation was a move toward maintaining site hydrology and controlling the volume of stormwater runoff.

11.2.8. Wilson, C.M. 2000. Chief Council. **Memo to RWQCB Executive Officers, State Water Board Order WQ 2000-11: SUSMP**. December 26. http://www.swrcb.ca.gov/rwqcb4/html/programs/stormwater/susmp/susmps_memo_122600.pdf

Brief Summary: SWRCB has issued general NPDES permits for designated construction and industrial activities and has issued CALTRANS permit.

11.3. **Local**

11.3.1. Anacostia Waterfront Corporation. 2007, June. **Anacostia Waterfront Corporation Environmental Standards.** http://www.anacostiawaterfront.net/Portals/0/documents/standards/20070601%20Final%20AWC%20Environmental%20Standards.pdf

Brief Summary: The Anacostia Waterfront Corporation's (AWC) Board of Directors approved comprehensive environmental standards that govern redevelopment along the Anacostia River. Significant stormwater requirements were included as part of the standards package stipulating a preference for green, vegetated control practices and establishing a one-inch stormwater retention and two-year, 24-hour storm treatment requirements. The AWC used the environmental standards as an opportunity to further its goal of using green controls to enhance redevelopment and provide advanced stormwater management.

11.3.2. Arendt, Randall. 1997, November. **Growing Greener: Putting Conservation Into Local Codes**. Natural Lands Trust, Inc. http://www.mass.gov/czm/growinggreener.pdf

Brief Summary: The publication, developed in Pennsylvania, discusses how municipalities can adjust the language of zoning regulation and direct the development process to protect water and land resources. Included is a discussion of how to use the development process to create an interconnected network of green open space via changes to zoning ordinances, municipal comprehensive plans and subdivision ordinances.

11.3.3. Kauffman G. & Brant, T. 2000. **The Role of Impervious Cover as a Watershed-based Zoning Tool to Protect Water Quality in the Christina River Basin of Delaware, Pennsylvania, and Maryland.** *Watershed Management 2000 Conference*. http://www.wr.udel.edu/publications/imperviouscoverchristinabasin.pdf

Brief Summary: (from document abstract) *The authors advocate amending the existing code to establish watershed-zoning districts based on percent impervious cover thresholds in the Christina River Basin of Delaware. By employing this concept in county and municipal zoning codes, smart growth can be concentrated in areas with existing infrastructure, while protecting the quantity and quality of Delaware's surface water supplies. Land use zoning based on impervious surface coverage should be considered as an effective, measurable, and scientifically defensible technique to protect stream water quality in the Christina River Basin and other watersheds in the Delaware Valley, the USA, and overseas.*

11.3.4. Los Angeles Regional Water Quality Control Board. 2000, March 8. **Standard Urban Storm Water Mitigation Plan for Los Angeles County and Cities in Los Angeles County.** http://www.swrcb.ca.gov/rwqcb4/html/programs/stormwater/susmp/susmp_rbfinal.pdf

Brief Summary: Regional boards use Standard Urban Stormwater Mitigation Plans (SUSMPs) in municipal stormwater permits. State Board considers SUSMPs as applying to new development and redevelopment. BMPs identified for treatment and control for specific development categories. The LA SUSMP includes the following categories:

- Single family hillside
- 100,000 sf commercial
- Auto repair
- Retail gas
- Restaurants

- Subdivisions – 10 to 99 units
- Subdivisions – 100 plus units
- Within/adjacent to/discharging to environmentally sensitive area
- Exposed parking lots of 5,000 sf or 25 plus spaces

11.3.5. Northeastern Illinois Planning Commission & Chicago Wilderness. 2003. **Conservation Design Resource Manual: Language and Guidelines for Updating Local Ordinances**. March 2003. http://www.chicagowilderness.org/pubprod/miscpdf/CD_Resource_Manual.pdf

Brief Summary: This publication is a guide for local governments interested in adopting conservation development practices in plans, zoning, and ordinances.

11.3.6. Portland, City of. **Portland City Code Chapter 17.38, Policy Framework, Appeals, and Update Process**.

Brief Summary: Portland's stormwater requirements are a good example of urban stormwater control standards. The code requires on-site treatment of stormwater and establishes treatment criteria that must be met. Infiltration with vegetated controls is the preferred method of treatment.

11.3.7. San Diego Municipal Code: Land Development Manual. 2003, May 30. **Stormwater Standards: A Manual for Construction and Permanent Storm Water Best Management Practices Requirements**. 58 pp. http://www.sandiego.gov/development-services/news/pdf/stormwatermanual.pdf

Brief Summary: This manual provides the stormwater standards for San Diego. Project review and permitting processes, BMP selection procedure construction stormwater BMP performance standards, implementation and maintenance of BMPs and permits are detailed, Examples of permanent stormwater management devices are provided. Ten appendices cover San Diego specific information pertaining to stormwater.

11.3.8. San Diego California Regional Water Quality Control Board. **Waste Discharge Requirements for Discharges of Urban Runoff from The Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of The County of San Diego, The Incorporated Cites of San Diego County, The San Diego Unified Port District, and the San Diego County Regional Airport Authority.** San Diego Region Order No. R9-2007-001. NPDES No. CAS0108758. 119 pp. http://www.waterboards.ca.gov/sandiego/programs/stormwater/sd%20permit/r9-2007-0001/Final%20Order%20R9-2007-0001.pdf

Brief Summary: This order applies to MS4s within the California Regional Water Quality Control Board - San Diego Region. The order renews the NPDES Permit and is based on several layers of regulations pertaining to stormwater at federal, state and local levels of jurisdiction . Discharge characteristics for watersheds are specified. Standards for reductions in pollutant discharge follows a maximum extend practicable (MEP) set of goals. Development planning is mandated in this order and requires the use of LID BMPs as part of the solution to controlling urban runoff pollution to augment end of pipe solutions, to be used in new developments, as part of retail gasoline outlet (RGOs) urban runoff control and in heavy industry applications. Construction activity, land use planning, watershed strategy as well as water quality monitoring are specified. Monitoring standards are defined, as are the respective roles of Co-permittees. Annual reporting standards, assigned collaborations and principle permittee responsibilities are detailed.

11.3.9. Santa Clara Valley Urban Runoff Pollution Prevention Program. 2005. **Hydromodification Management Plan – Final Report**. April 21, 2005.

Brief Summary: The RWQCB, San Francisco Bay Region, requires stormwater programs to develop and implement hydromodification management plans (HMPs). The Santa Clara Valley Urban Runoff Pollution Prevention Program was the first permit to include the new HMP requirements. The Program's hydromodification control standard requires that those who discharge stormwater manage increases in peak runoff flow and increased runoff volume where the increased volume or flow can cause erosion or siltation problems. The implemented HMP will limit post-construction runoff to pre-construction rates and/or durations.

11.3.10. Seattle, City of. (n.d.). **Seattle Green Factor**. http://www.seattle.gov/dpd/permits/greenfactor

Brief Summary: The Green Factor is an alternative approach for urban stormwater control requiring that 30% of a commercial site must be vegetated. This system encourages multiple layers of visible plantings and plantings in the public rights-of-way adjacent to the properties. The system is flexible and weights different landscaping practices according to their effectiveness. The square footage of each practice is multiplied by its green factor and then aggregated with the score of each additional practice to satisfy the requirements. Bonuses are also provided for utilizing rain water harvesting and low water-use plants.

11.3.11. Snohomish County Council, Snohomish County, Washington. 2006. Ordinance No. 06-044. **Relating to drainage development standards, making available for use the "Low Impact Development Technical Guidance Manual for Puget Sound;"** Amending Snohomish County code Section 30.63A.200; and adding a new chapter 30.63C to the Snohomish County Code.
http://www.co.snohomish.wa.us/documents/Departments/Council/Agendas/ord06044.pdf

Brief Summary: This LID ordinance applies to Snohomish County, Washington.

11.3.12. Spinner, Jenni. **Low-Impact Leader**. Public Works Magazine. May 2007. http://www.pwmag.com/industry-news.asp?sectionID=760&articleID=493013

Brief Summary: Seattle has been implementing LID for nearly a decade. Unimproved streets are being upgraded through the Street Edge Alternatives.

11.3.13. Stein, E. & Ebbin, M. 2005, November 3. **Watershed-Scale Planning for Aquatic Resources and Water Quality-Finding Opportunities for Regulatory Coordination**.

Brief Summary:

11.3.14. Thurston, H. W.; Goddard, H. C.; Szlag, D. & Lemberg, B. 2003, Sept./Oct. **Controlling Stormwater Runoff with Tradable Allowances for Impervious Surfaces**. *Journal of Water Resources Planning and Management.*

Brief Summary: The study evaluates the potential of trading impervious surface allowances to control stormwater runoff. A small watershed in the Cincinnati Area is used as a case study.

11.3.15. Walls, M. & McConnell, V. (2004, March). **Incentive-Based Land Use Policies and Water Quality in the Chesapeake Bay**. http://www.rff.org/Documents/RFF-DP-04-20.pdf

Brief Summary: In this paper, we discuss the ways that land use affects pollution in the Bay. We then analyze three economic incentive-based policies that could be used to alter land use patterns—purchase of development rights (PDRs), transferable development rights (TDRs), and development impact fees. The strengths and weaknesses of each policy are discussed. Finally, we discuss the issue of policy coordination, i.e., synchronizing policies focused directly on land use, such as TDRs, with input-based taxes. More research on this important policy issue is needed.

11.3.16. Woodard & Curran (2005, December 31). City of Salem, MA. **Stormwater & LID Ordinance**. http://www.woodardcurran.com/resource/Salem%20Storm-LID_ordinance_Final.pdf

Brief Summary: This LID Ordinance states what projects with in the City of Salem, MA must obtain a Stormwater & LID Permit and conform to the Stormwater & LID Regulations. This ordinance conforms with standards to meet NPDES requirements. The Stormwater authority is authorized to adopt an LID credit system which would allow the use of better site design practices to *reduce some requirements specified in the criteria section of the Regulations* (from the ordinance) LID is not defined *per se* in the ordinance definitions.

11.3.17. Woodard & Curran (2005, December 31). City of Salem Engineering Department. **Stormwater & LID Regulations**. http://www.woodardcurran.com/resource/Salem%20Storm-LID_Regulations_final.pdf

Brief Summary: This LID Code specifies stormwater management targets and design requirements for the City of Salem.

12. Resource Protection

12.1. State Water Resources Control Board (SWRCB), California Environmental Protection Agency, Division of Water Quality. 2001. **Santa Monica Bay Restoration Project Report to the Legislature**. http://www.swrcb.ca.gov/legislative/docs/2001/santamonicabay.pdf

Brief Summary: (from the document) *This Report makes specific recommendations for coordination of state policies and the Santa Monica Bay Restoration Project (SMBRP)* First, actions taken as part of the project are listed. Then the current issues confronting the project are identified and a proposal for a clear partnership entity to be created to oversee the project is presented. The recommendation is to form an inter-agency, collaborative state entity as defined in the report.

12.2. State Water Resources Control Board (SWRCB), California Environmental Protection Agency. 2004. **Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program**. May 20. http://www.swrcb.ca.gov/nps/docs/oalfinalcopy052604.doc

Brief Summary: Porter-Cologne Act is the principle law governing water quality control in the state. Applies to point and nonpoint sources and discharges to all state waters (e.g., surface water, wetlands, and groundwater). Regional control boards adopt regional water quality control plans (basin plans).

13. Hydromodification

13.1. Bannerman, Roger & Weber, Daniel. 2004. **Relationships between impervious surfaces within a watershed and measures of reproduction in Flathead Minnows**. Hydrobiologia. Vol 525. Num 1-3. Sept 2004. http://www.springerlink.com/content/l534457344m38314/

Brief Summary: Watershed landuse patterns and imperviousness levels were compared to flathead minnow reproductive measures. Reproductive measures were proposed as a indicator of water quality.

13.2. Booth, D. B. & Jackson, C. R. 1997. **Urbanization of Aquatic Systems – Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation.** *Journal of the American Water Resources Association* 22(5). http://faculty.washington.edu/dbooth/Booth_and_Jackson_1997.pdf

Brief Summary: The paper examines the urbanization impacts on lowland streams in western Washington. Using continuous hydrologic modeling, the researchers found that detention ponds designed by conventional event methodologies showed *serious deficiencies in actual pond performance when compared to their design goals*.

13.3. Guay, J. 1996. **Effects of Increased Urbanization from 1970's to 1990's on Storm Runoff Characteristics in Perris Valley, CA**. USGS Water Resources Investigations Report 95-4273.

Brief Summary: This study found a positive correlation between increased imperviousness/urbanization in Riverside, CA, an arid watershed, and an increase in the frequency of floods.

13.4. Horner, R.; May, C.; Livingston, E., Blaha, D.; Scoggins, M. & Tims, J. et al. (n.d.). **Structural and Non-Structural BMPs for Protecting Streams**. *Watershed Management Institute*. Florida, Crawfordsville http://www.chesterfield.gov/CommunityDevelopment/Engineering/LIDGrant/Studies/HornerMay2001Paper.pdf

Brief Summary: Three stream ecosystems were studied for the benefits of watershed forest, wetland, and riparian buffers. The watersheds with non-structural LID showed significant benefit. One study of a moderately high urban watershed found that even with structural BMPs help sustain aquatic biological communities.

13.5. May, C.W. (n.d.). **The Cumulative Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion**. www.psat.wa.gov/Publications/98_proceedings/pdfs/1a_may.pdf

Brief Summary: This study examines the relationship between land use practices – timber harvesting, agriculture, and urbanization - and small stream ecosystems and salmon populations. (from document) *The key objective was to determine the links between landscape-level conditions and instream environmental factors.* Discussion of each of the contributing factors to reductions in water quality details the specific findings of the study. The conclusion provides a list of stewardship focused performance based recommendations for improving the conditions in small streams in the Puget Sound Lowland Region so that the current degraded status may be changed to a more natural condition.

13.6. Maruya, K. & Stein, E. 2007. **Effects of Regionwide Fires on Deposition, Runoff, and Emissions to the Southern California Bight**. Southern California Coastal Water Resource Project. (On going) http://www.sccwrp.org/about/rspln2006-2007.html#rp

Brief Summary: This ongoing research will compare runoff and pollutant loadings in a natural watershed with severe burns and an unburned natural watershed. The post-fire and unburned areas will be compared; the areas of study are the wildfire areas in the Los Padres and San Bernadino National Forests in 2003. Paired watersheds will be determined, field data from at least four storms will be monitored and an isotope marker analysis will be conducted. The intent is to gain knowledge so that the cumulative impact of fire on attainment of water quality standards may be assessed.

13.7. Mount, J. F. 1995. **California Rivers and Streams: The Conflict Between Fluvial Process and Land Use**. Berkeley: University of California Press.

Brief Summary: The book describes the natural processes and functions of rivers that are impacted by traditional land uses.

13.8. Ross Taylor and Associates. 1999. **Using Stream Geomorphic Characteristics as a Long-term Monitoring Tool to Assess Watershed Function**. A Workshop Co-Sponsored by Fish, Farm, Forests, and Farms Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Humboldt State University. March 18 & 19. Proceedings edited by R.N. Taylor. Final Draft: July 2. McKinleyville, CA. http://www.rosstaylorandassociates.com/pdf/FFFC_Long-term_monitoring_Workshop_Proceedings.pdf

Brief Summary: There are several research papers included in the proceedings related to channel monitoring and stream quality. This is the proceedings of a two day workshop by the Fish, Forests and Farms Community (FFFC) ; this group was formed to: (from the document) *address land management and fisheries issues related to the ESA listing of coho salmon (and other salmonid species) in California* This committee has formulated 10 protocols targeted at actions which are intended to address salmonid habitat concerns. Papers focus on the channel monitoring protocol.

13.9. Stein, Eric D. 2005. (NB21F-05) **Effect of Increases in Peak Flows and Imperviousness on Stream Morphology of Ephemeral Streams in Southern California.** North American Benthological Society. April 2005. http://www.environmental-expert.com/files/19961/articles/4562/4562.pdf

Brief Summary: Technical Report investigates the impacts of urbanization on ephemeral or intermittent streams in Southern California. Study seeks to : (from the document) *establish a stream channel classification system for Southern California streams, assess stream channel response to watershed change, develop deterministic/predictive relationship between changes in impervious cover and stream channel enlargement and provide a conceptual model of stream channel behavior that may be used as the basis for a future numeric model*. Eight watersheds and eleven sites were selected for study.

13.10. Stein, E.D. & Zaleski, S. 2005. **Managing Runoff to Protect Natural Streams: The Latest Developments on Investigation and Management of Hydromodification in California**. Proceedings of a Special Technical Workshop Co-sponsored by: California Stormwater Quality Association (CASQA), Stormwater Monitoring Coalition (SMC), University of Southern California Sea Grant (USC Sea Grant). Technical Report #475. December 30. ftp://ftp.sccwrp.org/pub/download/PDFs/475_hydromodification_workshop.pdf

Brief Summary: (from document abstract) *Recent studies indicate that California's intermittent and ephemeral streams are more susceptible to the effects of hydromodification than streams from other parts of the United States. Physical degradation of stream channels in the central and eastern US can initially be detected when watershed impervious cover approaches 10%, although biological effects (which may be more difficult to detect) may occur at lower levels. In contrast, initial response of streams in the semi-arid portions of California appears to occur between 3% and 5% impervious cover. Hydromodification is best addressed with a suite of strategies including site design, on-site controls, regional controls, in-stream controls, and restoration of degraded stream systems.*

13.11. White, M. D. & Greer, K. A. 2000. **The Effects of Watershed Urbanization on the Stream Hydrology and Riparian Vegetation of Los Penasquitos Creek, CA.** *Landscape and Urban Planning.* 74 (2), 125-138. www.sciencedirect.com

Brief Summary: This study of Los Penasquitos Creek demonstrates the significant impacts impervious surfaces have on the character and integrity of stream and riparian ecosystems.

13.12. Zomorodi, K. 2007, March 12-14. **Effectiveness of Time of Concentration Elongation on Peak Flow Reduction**. 2nd National Low Impact Development Conference. http://www.bae.ncsu.edu/topic/lidconference07/

Brief Summary: This study shows the limits to lowering peak flows by extending the time of concentration in a Virginia context. Results suggest that (from document) *to achieve the objective of maintaining the peak flows of natural conditions, it may be more productive to focus on LID management techniques other than increasing Tc*.

14. Ancillary Programs

14.1. Air

14.1.1. Sabin, L.D. et al. 2006. **Atmospheric Dry Deposition of Trace Metals in the Coastal Region of Los Angeles, CA. Environmental Toxicology and Chemistry**. September. Vol 25, Iss. 9. pg 2334, 8 pgs. New York. http://entc.allenpress.com/entconline/?request=get-abstract&doi=10.1897%2F05-300R.1

Brief Summary: Study found substantial dry deposition of air pollution on urban watershed land surfaces in Los Angeles. This represents a potentially large source of trace metals to urban Los Angeles runoff based on comparisons with load estimates.

14.2. Water Supply

14.2.1. Beltran, S.M.; Singarella, P.N. & Katz, E. M. 2004. **Water at the Crossroads: The Intersection of Water Supply and Water Quality Issues and the Resulting Effect on Development**. American Bar Association Section of Real Property, Probate and Trust Law.

www.abanet.org/rppt/meetings_cle/spring2004/rp/resultingeffectondevelopment/beltran.pdf

Brief Summary: (from document abstract) *The purpose of this paper will be to examine the Permit (MS4 Permit) and highlight the issues raised by the Petitioners challenging the Permit in the Lawsuit, focusing on those issues most important to the developer/building community. The document discusses some legal issues with requiring LID.*

14.2.2. Chralowicz, D.; Dominguez, A.; Goff, T.; Mascali, M. & Taylor, E. 2001. **Infiltration of Urban Stormwater Runoff to Recharge Groundwater used for Drinking Water: A Study of the San Fernando Valley, California**. Doctorial Dissertation, University of California, Santa Barbara. www.bren.ucsb.edu/research/2001Group_Projects/Final_Docs/stormwater_final.pdf

Brief Summary: (from document abstract) Our study explored the use of infiltration basins that capture urban stormwater runoff as a means of increasing the reliability of local groundwater resources used for drinking water in the San Fernando Valley of Los Angeles County.

14.2.3. Grahl, C. L. 2000, Sept./Oct. **A Grand Plan for Water Conservation**. Environmental Design and Construction.

Brief Summary: The article describes how a planned Arizona community incorporates BMPs into a large-scale water conservation strategy for the development.

14.3. Thermal

14.3.1. Kieser, M. S. et al. 2004**. Stormwater Thermal Enrichment in Urban Watershed.** Water Environment Research Foundation (WERF). http://www.kieser-associates.com/condrain/thermal.htm *&* http://www.iwapublishing.com/template.cfm?name=isbn1843396831

Brief Summary: The report makes thermal reduction recommendations based on a five year thermal enrichment study of an urbanizing watershed in Portage, MI. The study identifies two key design criteria to reduce thermal stormwater enrichment: runoff abatement and infiltration. These goals are compatible with low impact development techniques. Specifically for BMPs, infiltration and vegetative shading will provide the most thermal reductions. Shading of impervious surfaces and open ponds provides some thermal mitigation, but should only be used as a secondary option.

14.4. Environmental Justice

14.4.1. Michel, S.M. 2002. **Testimony of Suzanne M. Michel, PhD. Water Resources Geography and Policy Environmental Policy Analyst, Institute for Regional Studies of the Californias, San Diego State University**. State Water Resources Control Board Hearing on the IID-SDCWA long-term transfer and the IID-SDCWA transfer EIS-EIR.

http://www.waterrights.ca.gov/IID/IIDHearingData/LocalPublish/NWF_Exhibit_14.pdf

Brief Summary: The document presents the term hydrocommons, a geographic region connected by a limited water resource, water transfers, and shared water quality and biological diversity problems. The policy paper puts stormwater runoff and pollution issues in the larger context of water scarcity, degraded water resources, and water transfers of Southern California.

14.4.2. Pendleton, L. et al. 2000. **Public Perceptions of Environmental Quality: A Survey Study of Beach Use and Perceptions in Los Angeles County**. Marine Pollution Bulletin 42(11):1155-1160 (2001). http://www.usc.edu/dept/economics/usclace/survey.PDF

Brief Summary: The study surveyed a representative cross-section of the Los Angeles population on their opinions of beach pollution and sources of opinion regarding water quality.